



PROGRAM MANAGER FOR ROCKY MOUNTAIN ARSENAL

U.S. ARMY
MATERIEL COMMAND

— COMMITTED TO PROTECTION OF THE ENVIRONMENT —

IRA-F AIR QUALITY MONITORING PROGRAM FINAL REPORT Version 2.0

VOLUME I
July 1991
CONTRACT NO. DAAA15-88-D-0024



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TECHNICAL SUPPORT FOR
ROCKY MOUNTAIN ARSENAL

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FINAL REPORT
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Prepared for:

Program Manager's Office for the
Rocky Mountain Arsenal

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REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
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1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE 07/00/91		3. REPORT TYPE AND DATES COVERED
4. TITLE AND SUBTITLE IRA F, AIR QUALITY MONITORING PROGRAM, FINAL REPORT, VERSION 2.0			5. FUNDING NUMBERS	
6. AUTHOR(S)			DAAA15 88 D 0024	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) EBASCO SERVICES, INC. LAKEWOOD, CO			8. PERFORMING ORGANIZATION REPORT NUMBER 91347R01	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) ROCKY MOUNTAIN ARSENAL (CO.). PMRMA COMMERCE CITY, CO			10. SPONSORING / MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES				
12a. DISTRIBUTION / AVAILABILITY STATEMENT APPROVED FOR PUBLIC RELEASE; DISTRIBUTION IS UNLIMITED			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) THIS REPORT FOCUSES ON ACTIVITIES OF THE INTERIM RESPONSE ACTION F (IRA-F) MONITORING PROGRAM AT RMA, AND IT PROVIDES AN ANALYSIS OF AIR QUALITY CONDITIONS AROUND BASIN F, BOTH DURING AND AFTER REMEDIAL ACTIVITIES. INCLUDED IN THIS REPORT ARE THE DETAILS OF THE AIR MONITORING AND ANALYTICAL PROCEDURES FOR IRA-F AND A SYNOPSIS OF OTHER AIR MONITORING PROGRAMS. THE AMBIENT AIR CONCENTRATIONS FOR A SET OF AIRBORNE TARGET COMPOUNDS ARE SUMMARIZED. TARGETS INCLUDE VOLATILE ORGANICS, SOME VOLATILE ORGANICS, METAL, ARSENIC AND PARTICULATES, THE RESULTS PROVIDE THE INFORMATION NECESSARY TO DESCRIBE THE POTENTIAL IMPACTS OF BASIN F OPERATIONS AND CLOSURE ON AMBIENT AIR QUALITY, AND TO CHARACTERIZE THE POTENTIAL SOURCES OF THE OBSERVED CONCENTRATIONS OF TARGET COMPOUND.				
14. SUBJECT TERMS CONTAMINANTS SOURCES, SAMPLING			15. NUMBER OF PAGES	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT	

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ACRONYMS AND ABBREVIATIONS

AA	Atomic absorbtion
AAC	Acceptable ambient conditions
AeroVironment	AeroVironment, Inc.
AES	Atomic emission spectrometry
ACET	Acetone
ACGIH	American Conference of Governmental Industrial Hygienists
AIHA	American Industrial Hygiene Association
ALDRN	Aldrin
Army	U.S. Army
ATSDR	Agency for Toxic Substance and Disease Registry
ATZ	Atrazine (2-chloro-4-ethylamino-6-isopropylamino-s-trianine)
BCHPD	Bicycloheptadiene
Chlordane	1,2,4,5,6,7,8,8-octachloro-2,3,3a,4,7,7a-hexahydro-4,7-methano-1H-idene
CLDAN	Chlordane
°C	Degrees Centigrade
cc/sec	Cubic centimeters per second
CCL ₄	Carbon tetrachloride
CDH	Colorado Department of Health
CFC	Chlorofluorocarbons
CF & I	Colorado Fuel and Iron Corporation
CFR	Code of Federal Regulations
CHCL ₃	Chloroform
CH ₂ CL ₂	Methylene chloride
CLC ₆ H ₅	Chlorobenzene
CLP	Contract laboratory program
CMP	Comprehensive Monitoring Program
CO	Carbon monoxide
COE	U.S. Army Corps of Engineers
CPF	Cancer potency factor
CPMSO	P-Chlorophenylmethyl sulfoxide
CPMSO ₂	P-Chlorophenylmethyl sulfone
CQAP	Chemical Quality Assurance Plan
CRL	Certified reporting limit
CS ₂	Carbon disulfide
CVAAS	Cold vapor atomic absorption spectrometry
C ₆ H ₆	Benzene
11DCLE	1,1-Dichloroethane
12DCLE	1,2-Dichloroethane
DBCP	Dibromochloropropane
DCPD	Dicyclopentadiene

ACRONYMS AND ABBREVIATIONS

(continued)

DDE	Dichlorodiphenylethane
DDT	Dichlorodiphenyltrichloroethane
DIMP	Diisopropyl methyl phosphone
DLDRN	Dieldrin
12DMB	1,2-Dimethyl benzene
DMDS	Dimethyl disulfide
DQO	Data quality objective
ENDRN	Endrin
EPA	U.S. Environmental Protection Agency
ETC ₆ H ₅	Ethyl benzene
°F	Degrees Fahrenheit
FY89	Fiscal Year 1989
FY90	Fiscal Year 1990
g/sec	Grams per second
GC/MS	Gas chromatography/mass spectrometry
GC/ECD	Gas chromatography/electron capture detection
GFAA	Graphite furnace atomic absorption
GFP	Good field practice
GMW	General Metal Works
GT	Greater than
HCBD	Hexachlorobutadiene
HEAST	Health Effects Assessment Summary Tables
H-Nu	Trade name for a photoionization type organic vapor analyzer
Hyman	Julius Hyman and Company
ICAP	Inductively coupled argon plasma
IRA-F	Interim Response Action F
IRDMS	Installation Restoration Data Management System
IRIS	Integrated Risk Information System
ISC	Industrial Source Complex
ISCLT	Industrial Source Complex Long-Term
ISCST	Industrial Source Complex Short-Term
ISODR	Isodrin
LCRL	Lower certified reporting limit
LOAEL	Lowest-observed-adverse-effect-level
LOF	Lack of fit
LQAC	Laboratory Quality Assurance Coordinator
LSD	Laboratory Support Division
LT	Less Than
m	Meter

ACRONYMS AND ABBREVIATIONS (continued)

mm	Millimeter
Malathion	0,0-dimethyl-s-(1,2-dicarboxyethyl) phosphorodithioate
MLTHN	Malathion
MEC ₆ H ₅	Toluene
MEK	Methyl ethyl ketone
MIBK	Methyl isobutyl ketone
mph	Miles per hour
MRI	Midwest Research Institute
MST	Mountain Standard Time
M-xylene	Meta-Xylene
NAAQS	National Ambient Air Quality Standards
ng	Nanogram
NIOSH	National Institute of Occupational Safety and Health
NOAEL	No-observed-adverse-effect-level
NO	Nitrous oxide
NO ₂	Nitrogen dioxide
NO _x	Nitrogen oxides
NNDMEA	N-nitrosodimethylamine
O ₃	Ozone
OCP	Organochlorine pesticides
OSHA	Occupational Safety and Health Administration
OVA	Organic vapor analyzer
O-xylene	Ortho-xylene
PEL	Personal exposure limit
PRTHN	Parathion (C ₁₀ H ₁₄ NO ₅ PS)
Pb	Lead
PM-10	Respirable particulates less than 10-microns
PNA	Polynuclear aromatics
ppb	Parts per billion
ppDDE	p,p-Dichlorodiphenylethane
ppDDT	p,p-Dichlorodiphenyltrichloroethane
ppm	Parts per million
PQAC	Project Quality Assurance Coordinator
PSD	Prevention of Significant Deterioration
PUF	Polyurethane foam
P-xylene	Para-xylene
QA	Quality assurance
QAP	Quality Assurance Program
QC	Quality control

ACRONYMS AND ABBREVIATIONS

(continued)

RfD	Reference-dose
RI	Remedial Investigation
RIFS3	Remedial Investigation/Feasibility Study, Task 3
RRT	Relative retention time
Sarin	Isopropylmethane fluorophosphonate
sccm	Standard cubic centimeters per minute
Shell	Shell Chemical Company
SO ₂	Sulfur Dioxide
SOP	Standard operating procedures
Stapleton	Stapleton International Airport
Supona	2-chloro-1-(2,4-dichlorophenyl) vinyl diethyl phosphate
SVOC	Semivolatile Organic Compounds
111TCE	1,1,1-Trichloroethane
112TCE	1,1,2-Trichloroethane
TCLEE	Tetrachloroethene
T12DCE	Trans-1,2-Dichloroethylene
TIC	Tentatively Identified Compound
TLV	Threshold Limit Value
TRCLE	Trichloroethylene
TSP	Total Suspended Particulates
µg	Microgram
µg/m ³	Micrograms per Cubic Meter
µm	Micrometer or micron
USATHAMA	U.S. Army Toxic and Hazardous Materials Agency
USAEHA	U.S. Army Environmental Hygiene Agency
VOC	Volatile Organic Compounds
X/Q	Relative Concentration
XYLEN	Xylenes

EXECUTIVE SUMMARY

This report focuses on activities of the Interim Response Action F (IRA-F) Air Monitoring Program at Rocky Mountain Arsenal, and it provides an analysis of air quality conditions around Basin F, both during and after remedial activities. Included in the report are the details of the air monitoring and analytical procedures for IRA-F and a synopsis of other air monitoring programs. The ambient air concentrations for a set of airborne target compounds are summarized. Targets included volatile organics, semi-volatile organics, metals, arsenic, and particulates. The results provided the information necessary to describe the potential impacts of Basin F operations and closure on ambient air quality, and to characterize the potential sources of the observed concentrations of target compounds.

Sampling around Basin F began with a Remedial Investigation study in 1986 to 1987, and continued with a program conducted during remedial activities (March 1988 to May 1989). A special Odor monitoring program overlapped the Basin F program and extended from October 1988 to May 1989. The IRA-F program, conducted from May 1989 through September 1990, was intended to analyze air quality conditions after the closure of Basin F.

For all target analytes, the mean and extreme concentrations during these periods are presented. Basin F remedial activities appeared to be a source for several of the target compounds, but after the completion of the waste pile cap, the impact of metropolitan Denver emissions on air quality dominated any impacts from the former Basin F area. Of the volatile organics, bicycloheptadiene, chloroform, dicyclopentadiene and dimethyl disulfide, were clearly related to Basin F emissions during remediation, but following completion of the cap only chloroform was detected around the former Basin F at measurable concentrations. Of the semivolatile organics, pesticides including Dieldrin, Aldrin, Endrin, and Isodrin were still being emitted from the former Basin F, but at a substantially reduced rate compared to emissions during remedial activities. Both the metals and suspended particulates were also emitted during remedial activities, but upon completion, their concentrations were representative of background urban-area levels. Chromium and mercury levels were substantially higher during remedial activities, but were rarely detected

following completion of the Basin F IRA. A clear seasonal cycle in the target compound concentrations is also discussed. Volatile organics tend to have highest concentrations in the winter months associated with the strong Denver area atmospheric inversion conditions. The detected pesticides had the highest concentrations in late summer or early fall, associated with the relatively warm temperatures and dry conditions at that time of year.

The IRA-F program also sampled and analyzed potential emissions from the waste pile and the former Basin F floor caps for volatile organics and semivolatile organics, but reported no signs of a breach or any indications of localized "hot spots." The IRA-F program sampled and analyzed the emissions from the waste pile, storage tank, and Pond A vents. On the waste pile, the emissions from certain vents were much higher than from other vents. Chloroform was detected at the highest concentrations at the vents. Bicycloheptadiene and dicyclopentadiene were also detected in the waste pile vents. At Pond A, the Freon compounds and chloromethane were detected in the highest concentrations. At the tanks, the vapor contents were homogeneous, with highest concentrations of chloromethane, dimethyl disulfide, and acetone. The vent sampling effort indicated a notable increase in the concentrations of target analytes from the spring to the late summer sampling effort, particularly at the tanks. At the waste pile vents, there was a steady increase in emissions during the IRA-F monitoring period.

For the target analytes, a set of "acceptable ambient concentrations," or AACs, was developed, based on an assumed seven-year exposure period, for the on-site workers and the off-site residents (both small children and adults), and these were compared to the sampling results. The comparisons were made for both the short-term (24-hour) and long-term average concentrations. Results showed that there were no exceedences of the short-term AACs. Estimated concentrations of dibromochloropropane, Dieldrin and chromium were above the long-term or chronic AACs for small children off site. The measured or estimated levels were below the chronic AACs for on-site workers and off-site adults. Except for chloroform, Aldrin and Dieldrin the sampled concentrations of all target compounds which exceed the AACs can be attributed to non-Arsenal sources.

1.0 INTRODUCTION

1.1 PURPOSE OF THE PROGRAM

Following the completion of the Interim Remedial Activities at Basin F on Rocky Mountain Arsenal (RMA) in May 1989, the Program Manager's Office for the Rocky Mountain Arsenal (PMRMA) established an ambient air quality monitoring program for selected sites near Basin F. This program was called Interim Response Action F (IRA-F) and was one of a number of larger scale interim response activities at RMA. Under terms of its Technical Support Services contract with Ebasco Services Incorporated (EBASCO), PMRMA issued a task order to collect and analyze post-remediation ambient air quality samples around Basin F. The objectives of the IRA-F air monitoring task were to determine the ambient concentrations of selected (target) compounds, to characterize the improvement of air quality conditions following Basin F closure, to provide baseline data for addressing potential sources of the observed concentrations, and compare the results of the monitoring effort to health guidelines or to developed "acceptable ambient concentrations." Secondary objectives included assessment of emissions from the Basin F waste pile cap, the clay and synthetic cap which covers the Basin F floor, the tank farm and the liquid waste storage pond.

One of the IRA-F sampling goals was to provide comparable follow-on data from previously monitored sites and to complement the concurrent air quality sampling activities being conducted under the Comprehensive Monitoring Program (CMP) at RMA. This report includes comparisons to CMP data and to data from preceding studies where it is pertinent. The program was designed to monitor air quality during the period from the completion of the Basin F IRA in May 1989, through the potential award of a comprehensive air quality monitoring program at RMA which was targeted for October 1990. Ultimately, the IRA-F program continued sampling until January 1991, when a subsequent task award assumed responsibility for monitoring at the IRA-F sites.

1.2 GENERAL PROGRAM SCOPE

The IRA-F program included sampling for target compounds in the ambient air around Basin F. These target compounds included volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), organochlorine pesticides (OCPs), metals, arsenic, mercury, total suspended particulates (TSP) and respirable particulates (PM-10). These samples were collected and analyzed in accordance with methods that were approved by PMRMA. The data produced by this effort were processed and stored in accordance with the Installation Restoration Data Management System (IRDMS), also established by PMRMA. Generally the sampling techniques followed those established and approved by the United States Environmental Protection Agency (EPA). Ambient air quality data were collected on the EPA six-day sampling schedule at seven sites during the first two months of the program and were collected at five sites for the remainder of the effort. Routine sampling was conducted from May 1989 through September 1990, with follow-on sampling conducted from October 1990 through mid-January 1991.

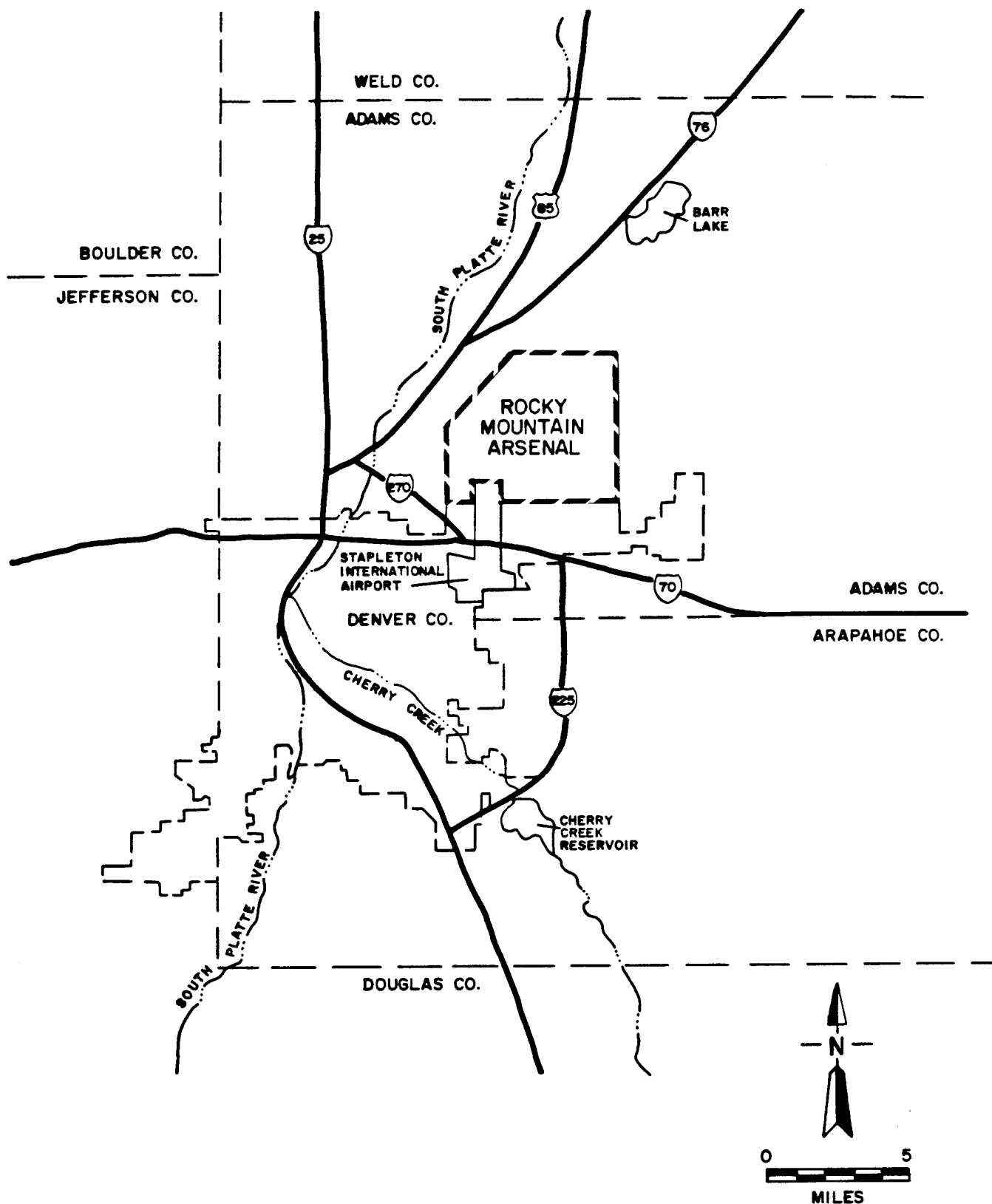
In addition to the regular ambient air sampling, several supplemental sampling efforts were undertaken. A real-time Basin F cap and vent monitoring effort was conducted to sample potential emissions from the restored Basin F floor, the waste pile cap, the tank farm and the liquid storage pond. Under this effort total organics were monitored monthly for the first five months, and quarterly thereafter. A sampling program which used evacuated stainless steel canisters for grab sampling was employed to characterize emissions from the waste pile vents, Pond A vents and the tank vents. Another short-term separate sampling effort, that employed flux chambers to capture soil surface emissions, was used to characterize emissions during three episodes from the clay cap covering the Basin F floor.

1.3 OUTLINE OF REPORT

This report summarizes the results of activities conducted under the IRA-F program, and includes comparative analysis of results from IRA-F, the CMP, and previous air quality monitoring programs at or near Basin F. Section 2 provides a brief background of the site and operations, the air quality and meteorological conditions, and a synopsis of monitoring tasks for this and

other air quality monitoring programs. Section 3 provides a discussion of program strategy and methodology. Included in this section is a discussion of the field program, the special sampling at the waste pile, Basin F cap, tanks, and Pond A, the use of meteorological data, data processing techniques, laboratory analytical procedures, and the quality assurance (QA) program. The analytical results for each of the target analyte groups and for the cap and vent monitoring program are presented in Section 4. In this report, the sampling results are reported for discrete time periods referred to as Phase 1, Phase 2, Phase 3 and Phase 4. These phases are defined in more depth in Section 3.1. The results of the QA activities are described in Section 5, and ambient air quality results are compared to acceptable ambient concentrations in Section 6. Conclusions related to the monitoring program are provided in Section 7.

Throughout the report, data and conclusions from other ambient air quality programs at RMA are cited for comparison to IRA-F data and conclusions. These programs included the Air Remedial Investigation (RI) program, the Odor Program, the Basin F Air Monitoring Program which was conducted during remedial activity, and the Comprehensive Monitoring Program air monitoring effort.



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Program Manager for
Rocky Mountain Arsenal

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Figure 2.1-1

Rocky Mountain Arsenal General Location Map

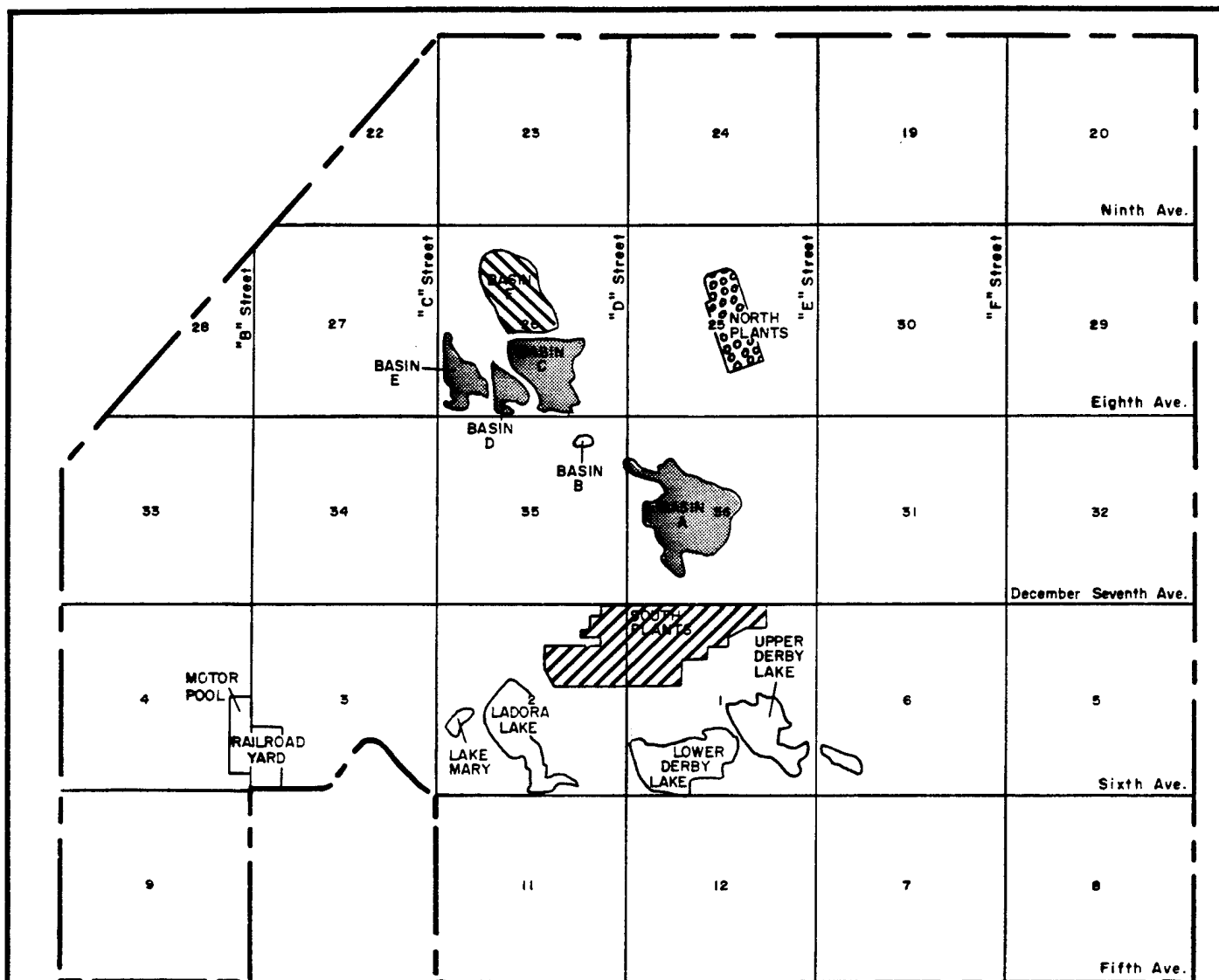
2.0 BACKGROUND

2.1 SITE BACKGROUND INFORMATION






Rocky Mountain Arsenal (RMA) encompasses more than 17,000 acres (27 square miles) northeast of Denver, Colorado in western Adams County (Figure 2.1-1). It was established in 1942 and was initially used as a manufacturing facility for chemical and incendiary munitions, and was used for demilitarization of chemical munitions. Industrial chemicals were manufactured at RMA from 1947 to 1982. Over the years a number of manufacturing, storage and transportation facilities were built to support RMA activities. The RMA facilities and containment structures which are discussed in this report are identified in Figure 2.1-2. Other locations have been included to illustrate the general layout of RMA.

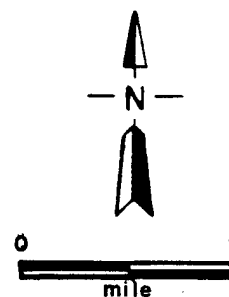
From 1943 to 1950 RMA manufactured and distilled stocks of Levinstein mustard, demilitarized several million rounds of mustard-filled shells, and test-fired mortar rounds filled with smoke-producing materials and high explosives. During this period many types of obsolete World War II ordnance were destroyed by detonation or burning. Manufacturing facilities built by the U.S. Army (Army) between 1950 and 1953 were used in the production of isopropylmethyl fluorophosphonate (Sarin), a nerve agent. Sarin manufacture continued until 1957, and Sarin munitions-filling operations continued until late 1969. Phosgene and cyanogen chloride munitions were demilitarized by the Army during the period from 1965 to 1969. Between 1943 and 1974, mustard munitions were demilitarized. Sarin munitions were demilitarized from 1973 to 1976 (Melito & Moloney, 1978).

In 1947, the Army leased portions of RMA to Colorado Fuel and Iron Corporation (CF & I) and Julius Hyman and Company (Hyman). Colorado Fuel and Iron manufactured chlorinated benzenes and dichlorodiphenyltrichloroethane (DDT). Hyman produced a variety of pesticides, insecticides and herbicides. In 1951, Shell Chemical Company (Shell) assumed portions of the Hyman lease.



LEGEND

-  Particulates, Asbestos, Volatile Organic Compounds, Semivolatile Organic Compounds
-  Particulates, Volatile Organic Compounds, Metals, Semivolatile Organic Compounds, Arsenic, Mercury
-  Particulates, Metals, Arsenic, Mercury, Semivolatile Organic Compounds
-  Particulates, Asbestos
-  Particulates



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Figure 2.1-2

Potential Contaminant Source Locations on
Rocky Mountain Arsenal

From 1943 to 1956, water and wastewater from all RMA operations was discharged into Basin A, located in Section 36. The area where Basin A is located was selected because it contained a playa, a natural shallow basin. At various times during operations at RMA, other small basins in Section 36 were used in the effluent storage system. These were incorporated into Basin A when it was enlarged. An impoundment dike at the low end of the basin was raised 5 feet in 1952 to handle the additional waste generated by the Sarin plant. Basin F, a lined disposal pond, was constructed in 1956 to contain liquid effluent from all the previously used basins as well as anticipated future wastes. Transfer of liquids from other effluent storage basins to Basin F was completed by 1958.

2.1.1 Potential Contaminant Sources

Potential sources of airborne contaminants within RMA boundaries were identified and air quality and meteorological monitoring stations were located near them. Previous air monitoring studies and remedial investigations conducted at RMA indicated that RMA sources of emissions existed at the South Plants area, throughout Sections 36 and 26, and in and around Basin F. After production and demilitarization activities ceased, there were no longer discrete or active point sources of emissions at RMA. Instead, the sources were large area sources of fugitive organics or particulates, whose emissions were a function of atmospheric conditions, surface cover and the contaminants' physical state. These sources, under typical conditions, appear not to pose a major air quality problem. However, remediation activities such as the Basin F Interim Remedial Action Program created temporary impacts on air quality due to excavation, dirt hauling, materials removal and waste pile construction.

Based upon historical records of RMA disposal activities and known chemical spills, the South Plants area, Basin A and Basin F are suspected as the largest potential sources of fugitive airborne emissions. Other minor potential sources may also contribute to airborne levels of contaminants.

2.1.2 South Plants Manufacturing Complex

The South Plants area was used by CF & I, Hyman, Shell and the Army from the early 1940s through the early 1980s to produce chemicals including pesticides, herbicides, insecticides and chemical weapons. Although production activity has ceased at the South Plants facilities, contaminants are still resident in soil and ground water; and under certain conditions, airborne organic contaminants have been detected. There are presently no open waste storage basins within the South Plants area. The bottom sediments of the small lakes near South Plants are known to contain chemical contaminants, but are not suspected of contributing significantly to the airborne emissions.

2.1.3 Basin A

Basin A is located in Section 36 and was the original disposal area for liquid effluent from South Plants activities. When the North Plants complex came on line, wastes from that operation were discharged into Basin A as well. When Basin F was completed and put on-line, discharge of wastes to Basin A was discontinued. Currently, the basin remains dry during most of the year, with some minor ponding of precipitation during the wetter months, particularly after a heavy summer rain. During the winter, the basin becomes extremely dry and dusty. Strong winds during the spring months previously caused severe dust conditions within the basin. Dust suppressants were applied to alleviate this condition and have contributed to control of windborne particulates.

Organics, including pesticides and Army chemical agent wastes, were discharged into Basin A from 1943 until Basin F was put on-line. Inorganic metals and inorganic nonmetals were also present. A sample of windblown dust collected from Basin A in September 1977 yielded a variety of contaminants. Chemical analyses revealed the presence of Aldrin, Dieldrin, Endrin, Isodrin, chlorophenylmethyl sulfide, chlorophenylmethyl sulfoxide, chlorophenylmethyl sulfone, dithiane, copper, arsenic and mercury.

2.1.4 Basin F

Basin F was a 93-acre, asphalt-lined basin in Section 26 with a liquid holding capacity of 245,000,000 gallons. Basin F was constructed in late 1956 to hold all industrial liquid effluent and wastewater generated at RMA. By 1958 the liquids from Basin A had been transferred to Basin F and effluents from both the South Plants facility and the North Plants facility were ultimately discharged there. The 3/8-inch thick asphalt liner was covered with a 12-inch thick layer of soil to help protect it from erosion and sun damage. Section 2.2.2 provides a discussion of the Basin F cleanup activities.

2.2 BACKGROUND OF PREVIOUS BASIN F STUDIES

The disposal history of Basin F was well documented during its operation, therefore, contaminants known to reside in Basin F have also been well documented. Studies on the Basin F liquid indicated that its contaminants included metals, alcohols, fluoride, chloride, insecticides, chlorinated organics, chlorophenylmethyl sulfone (CPMSO₂), pesticides, chlorophenylmethyl sulfoxide (CPMSO), phosphorous, p,p'-dichlorodiphenylethane (ppDDE), sulfate, p,p'-dichlorodiphenyltrichloroethane (ppDDT), diisopropylmethyl phosphonate (DIMP), phenols and dicyclopentadiene (DCPD). These studies also indicated that the Basin F liquids were relatively homogeneous.

A study performed in 1982 by the U.S. Army Corps of Engineers (COE) Waterways Experiment Station (WES) (WES, 1982) evaluated the contaminant distribution in Basin F. The study included development of sampling protocols for Basin F materials, leach testing and chemical analysis of numerous soil cores extracted from borings drilled beneath the basin liner. The results of this study indicated the presence of the following contaminants: acetophenone, fluoride, Aldrin, Isodrin, arsenic, mercury, chlorophenylmethyl sulfone, metals, chlorophenylmethyl sulfoxide, pentachloroethane, dibromochloropropane, tetrachloroethylene, dithiane, toluene, Dieldrin, trichloroethylene, DIMP, xylene, dimethyl phosphate and Endrin.

The U.S. Army's Environmental Hygiene Agency (USAEHA) sampled air near Basin F in November 1980 (National Space Technology Laboratories, 1980). This sample contained dimethyl acetamide, dimethylmethyl phosphonate, toluene and benzaldehyde (benzyl alcohol). In January 1981, this agency again sampled air near Basin F and found: diethyl ether, chloroform, 1-hexanol, benzene, hexane, n,n-dimethylaceto acetamide (NNDMA), DIMP, toluene, dibromochloropropane, ethyl benzene and meta-, ortho-, and para- (m-,o-,p-)xylene (U.S. Army, 1981).

An ambient air quality assessment was also conducted southeast of Basin F from April to September 1980 (USAEHA, 1981). Arsenic, cadmium, mercury, Aldrin, Dieldrin and Endrin were detected. However, arsenic, cadmium, copper, lead and mercury levels were not significant. The air was sampled for pesticides from September through December 1980, at which time Aldrin, Endrin and Dieldrin were detected.

In April and May 1982, the USAEHA conducted tests to monitor airborne emissions from Basin F liquids (USAEHA, 1982). The USAEHA evaluated various adsorption media for collecting Basin F emissions. Although this study did not attempt to characterize ambient air emissions near Basin F, the findings indicated potential for future studies to detect such contaminants as Aldrin, bicyclo-2,2,1-heptadiene, chloromethylsulfonyl benzene, dichlorobenzonitrile, Dieldrin, dimethyl disulfide, dimethylmethyl phosphonate, dimethylaceto acetamide, dipropyl amine and isocyanomethane.

The following subsections summarize several air monitoring studies that were precursors to the IRA-F program. These programs are described here to give a background of the previous or concurrent air monitoring activities at RMA and around Basin F. Results from these studies have been used for comparison to IRA-F data where supplemental data were useful. These programs included the Remedial Investigation (RI) Study of 1986 to 1987, the Basin F Air Monitoring Program, which was conducted as part of the Basin F Remedial Action from March 1988 to May 1989, a special Odor Program (sampling) conducted in conjunction with Basin F cleanup from

August 1988 to May 1989, and the CMP air monitoring effort which was begun in 1988 and continued concurrent with the IRA-F program. The pertinent sampling and analytical information is summarized below; for extensive details, the reader is referred to individual project reports which are cited in the text. Table 2.2-1 presents a summary of the applicable study data for the Basin F area. Not all studies previous to IRA-F are cited in this table.

2.2.1 The Basin F Air Remedial Investigation Program

The Air RI Program began in 1987 and was to investigate the nature and extent of atmospheric contamination existing at that time. The purpose of the data collection was support of other remedial investigations, endangerment assessment, and feasibility studies at RMA which were planned for the near future. Sampling began in the spring of 1987 and continued to the fall of 1988. Results were provided in the project report (ESE, 1988).

The RI air program consisted of sampling for the basic groups of target analytes, including VOCs, SVOCs, asbestos, metals, TSP, and PM-10. Meteorological data were also collected during this program. Total suspended particulates and PM-10 were collected on a 6-day schedule for a 24-hour collection period, following the EPA and Colorado Department of Health (CDH) sampling schedule. Total suspended particulates were collected at 12 sites and PM-10 were collected at 3 sites. Asbestos was sampled for an 8-hour collection period at 4 sites every 2 weeks. Volatile organic compounds and SVOCs were sampled during "high event" episodes, which were selected based on meteorological conditions which would enhance emission of the target analytes. Seven VOC and five SVOC high event days were selected, and sampling was conducted around suspected sources of the target analytes. Metals, arsenic and mercury were sampled on 12 high event days at four fixed and four mobile sites for each event. Sampling and analyses were conducted in accordance with recognized reference methods. Meteorological data used by this program were collected at three separate 10-meter towers.

Results of this program are included in Section 4 in terms of comparisons to the subsequent monitoring programs. The results showed that at RMA the air quality standards for TSP and

Table 2.2-1 Summary of Available Study Data for the Basin F Area

Study Report	Performed By	Date
Project Eagle Phase II Demilitarization and Disposal of the M34 Cluster at the Rocky Mountain Arsenal	J. Melito and W. Maloney	1978
Ambient Air Quality Assessment	R. L. Hanson	1981
EDCMB Air Sampling in January 1981	U.S. Army Environmental Division Contamination Migration Branch	1981
Evaluation of Contamination Distribution in Basin F	U.S. Army Corps of Engineers	1982
Evaluation of Organic Vapor Emissions, Basin F, Rocky Mountain Arsenal, Commerce City, Colorado. Part II. Field Study Results and Health Risk Assessment, June - August 1982. Final Report.	U.S. Army Environmental Hygiene Agency (USAHEA)	1982
Rocky Mountain Arsenal Final Technical Plan	Environmental Science and Engineering (ESE)	1987
Air Quality Assessment for the CMP	R. L. Stollar	1988; 1989; 1990; 1991
Basin F Interim Action Close-Out Safety Report	EBASCO	1989

PM-10 were not exceeded, and that the highest readings for particulates were noted at the RMA boundaries. No asbestos was detected. Volatile organic compounds were sampled around Basin F for all seven events, and results showed detections of methylene chloride and one detection of chloroform along with other nontarget compounds. Three SVOC sample events were conducted around Basin A and two were conducted around Basin F. Around Basin F, Aldrin, Dieldrin, Endrin, and Isodrin were detected. All but one of the VOC and SVOC events were conducted from May through August of 1987. The most prevalent airborne metal was copper. Lead was detected in a majority of samples around South Plants. Mercury was not found above the detection limit in any samples.

Though the RI data were limited in terms of spatial extent and scope, especially in comparison to subsequent programs, the results provided a suitable characterization of conditions at RMA prior to the remedial action at Basin F. The results from metals and organic compound sampling provide conservative estimates of background concentrations, because these analytes were sampled on high event days when emissions or impacts were expected to be highest.

2.2.2 Basin F Interim Action Cleanup and Air Monitoring Activities

All aqueous waste discharges into Basin F were stopped in December 1981. A major interim response action was initiated at Basin F in early 1988. During the Basin F Interim Action at RMA, Basin F liquid was transferred to sealed storage tanks and a double-lined holding pond. A double-lined waste storage pile and a double-lined leachate pond were constructed, and Basin F sludges were dried and stabilized with soil. The final stage of the cleanup involved transfer of the mixed sludge/soil into the waste pile, grading of the waste, and capping the pile with clay, geonet and geotextile. When the waste pile was completed, final grading and reseedling of the waste pile and restored basin were performed.

2.2.2.1 Basin F Air Sampling Strategy

The air quality monitoring program was concerned with monitoring ambient air in the perimeter zone (immediately surrounding the work zone) and off-site (approximately one mile from

Basin F) during the Basin F cleanup. The main objectives of this program were to determine ambient concentrations and to what extent off-site migration of specific contaminants was occurring. Based on prior analyses of soils, water and air near Basin F, a selected list of target analytes was compiled for each group of "type compounds." Table 2.2-2 presents the target list of compounds sampled for quantification in ambient air during the cleanup. Separate samples, media and analytical techniques were used for these groups of compounds. An additional objective was to provide characterizations of nontarget SVOCs and VOCs as well.

Air quality sampling was conducted by drawing a volume of air through a collection medium, such as a filter or sorbent trap, at specified locations, frequencies and time durations. For the Basin F cleanup program, the volumes and media were specifically selected based on several groups of target compounds that included: particulates, metals, VOCs, SVOCs, ammonia and mercury. Samples were collected during specific 24-hour target periods. To provide a conservative estimate of off-site migration, and to generate data that would provide a source characterization, the sampling methodology called for specific monitoring schedules at specific sites. Sampling site locations for the Basin F air monitoring program were given identification numbers for ease in data tracking. These sites were designated with the letters "BF," and their locations are provided in Figure 2.2-1. The scope of the sampling program included on-site and off-site ambient air sampling. On-site sampling was sampling within the perimeter and at the work site. Off-site sampling was conducted at sites which were outside the perimeter, but within RMA. Throughout this report, established sample sites which collected on-site samples are referred to as "perimeter sites." Sites BF-1, BF-2, BF-3 and BF-4 were designated as perimeter zone sampling sites, and sites BF-5, BF-6 and BF-7 were designated as the off-site (outside the work area) sampling locations.

2.2.2.2 Basin F Air Sampling Techniques

A variety of air monitoring and sampling measurement techniques was used to determine airborne concentrations of compounds present at the perimeter zone and off-site areas. The collection and analytical techniques focused on groups of compounds as well as specific individual compounds.

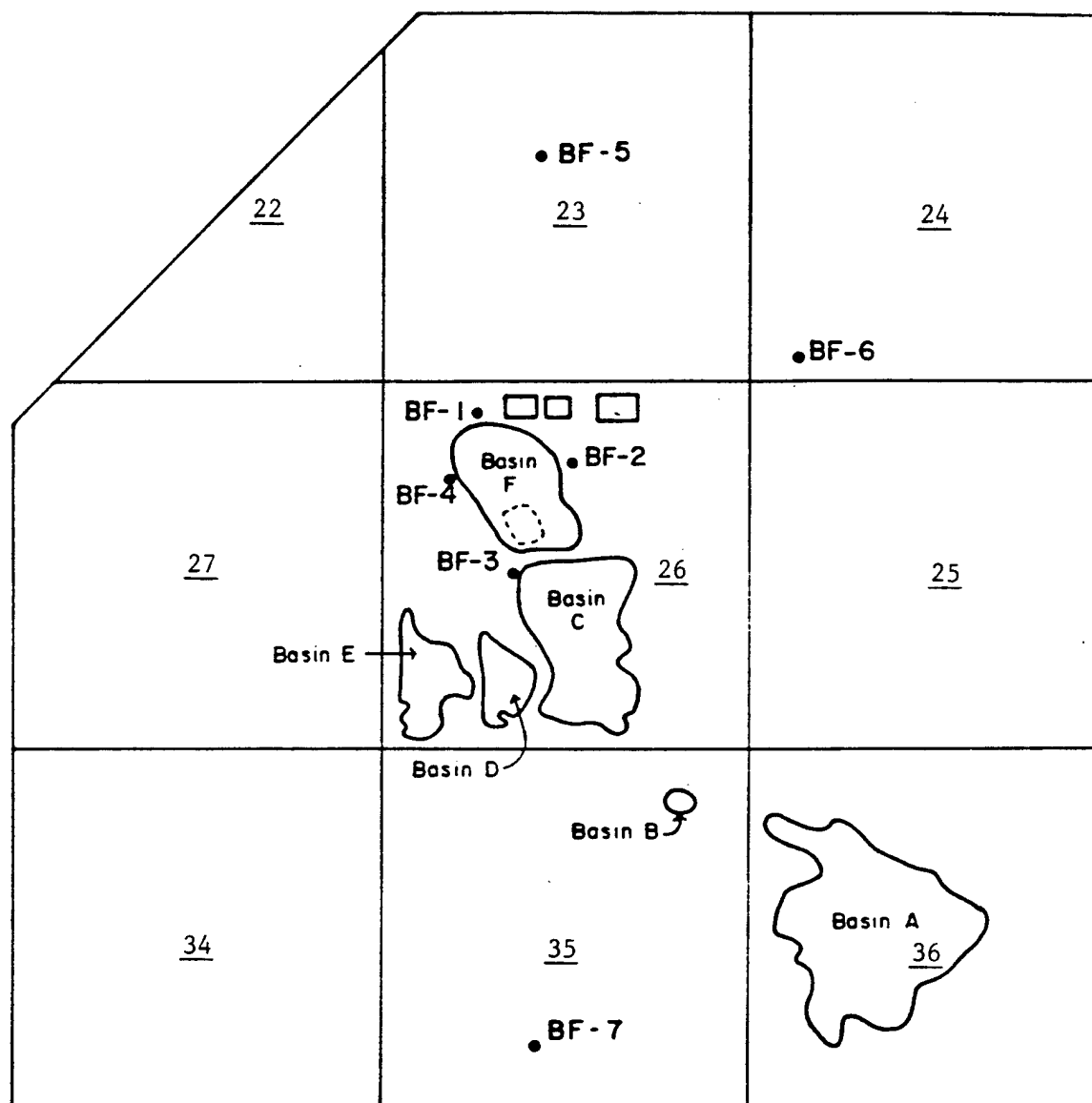
Table 2.2-2 Basin F Air Sampling Target Compounds

<u>Target Volatile Analytes</u>	<u>Target Metals</u>
Acetone	Arsenic
Benzene	Cadmium
Bicycloheptadiene	Chromium
2-Butanone* (methyl ethyl ketone)	Copper
Carbon disulfide*	Lead
Carbon tetrachloride	Zinc
Chlorobenzene	Mercury
Chloroform	
1,1-Dichloroethane	<u>Other Analytes</u>
1,2-Dichloroethane	
Dicyclopentadiene	Total Suspended Particulates
Dimethyl disulfide	Ammonia
Ethylbenzene	
Hexachlorobutadiene*	
Methyl isobutyl ketone	
Methylene chloride	
Tetrachloroethylene	
Toluene	
1,1,1-Trichloroethane	
1,1,2-Trichloroethane	
Trichloroethene	
Total xylenes	
m-Xylene	
o-Xylene	
p-Xylene	

Target Semivolatile Analytes

Aldrin
 Atrazine
 t-Chlordane
 p,p'-Dichlorodiphenylethane
 p,p'-Dichlorodiphenyltrichloroethane
 Dieldrin
 Endrin
 Isodrin
 Malathion
 Parathion
 Supona

* Added while the Basin F project was in progress



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Figure 2.2-1

Basin F Air Quality Monitoring Locations

National Institute of Occupational Safety and Health (NIOSH) and EPA approved methods were used for on-site and off-site sampling. Laboratory analysis was performed by an American Industrial Hygiene Association (AIHA)-accredited laboratory which was also an EPA Contract Laboratory for Superfund Priority Pollutant Analysis.

Techniques employed to sample general groups of compounds included the use of several models of General Metal Works (GMW) samplers. Volatile organic compounds were sampled using EPA Method T0-1, followed by a variation of the gas chromatography/mass spectrometry (GC/MS) EPA Method 624 for VOC Analysis (EPA, 1984). This technique was applicable to volatile, nonpolar organics having boiling points in the range of 80 to 200 Celsius (°C). The method employed a TenaxTM trap to adsorb the organic species and a backup trap of Tenax-and-charcoal. General Metal Works (GMW) Model VOTA samplers were used for sample collection. (VOTA is the model designation assigned to this sampler by GMW.) Semivolatile organic compounds were sampled using EPA Method T0-4, followed by variations the EPA Method 625 GC/MS Priority Pollutant Analysis and the EPA Method 608 Gas Chromatography/Electron Capture Detection (GC/ECD) Pesticide Analysis (EPA, 1984). This method involved drawing air through a quartz filter and into a polyurethane foam plug (PUF) to trap the SVOCs. A modified high volume sampler GMW Model PS-1 sampler was used for sample collection. Metals and TSP were sampled using the standard EPA High Volume sampling technique, followed by the standard EPA Gravimetric Analysis (EPA, 1983) for TSP, NIOSH Method 7300 for inductively coupled argon plasma (ICAP) Metals Analysis (NIOSH, 1984). The glass fiber filters used for TSP collection were first weighed to determine the concentration of TSP and then analyzed for metals. Samples were collected using a GMW Hi-Volume (Hi-Vol) Sampler.

Other specific compounds sampled were mercury and ammonia. Each of these compounds was sampled using sorbent tubes connected to separate sampling ports on GMW VOTA samplers. Mercury sampling employed glass tubes filled with hopcalite sorbent (HydrarTM manufactured by SKC, Inc.), which was subsequently analyzed by flameless cold vapor atomic absorption

(CVAA). Ammonia sampling utilized silica gel sorbent tubes. Analyses on these samples were accomplished using NIOSH Method S347 with an ammonia ion-specific electrode.

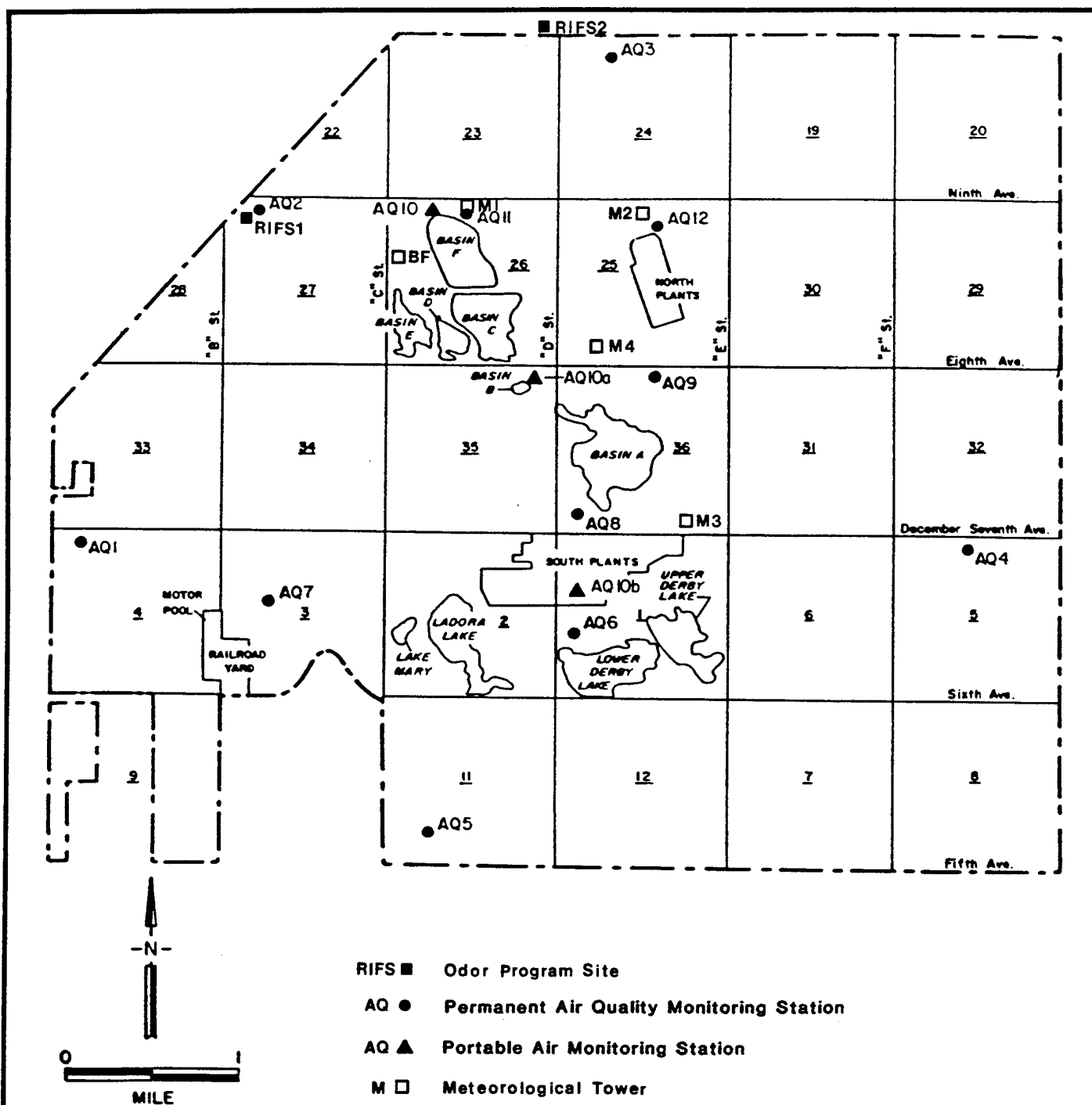
Additionally, real-time monitoring was conducted within the work area and along the perimeter at fixed and downwind locations. This monitoring included the use of organic vapor sensors (OVAs) and photoionization detectors (HNus), ammonia (colormetric) and total particulate (dust) monitors. Concurrent meteorological data were monitored, and a real-time air dispersion model was employed to predict the area of maximum impact.

Results from the Basin F air monitoring program are discussed along with the IRA-F results in Section 4 of this report.

2.2.3 Odor Program

A noticeable odor which had caused periodic complaints from nearby residents increased during cleanup activities. Due to these complaints an odor response program was initiated on August 5, 1988. Odor complaint responses were initiated when telephone complaints were received. Response personnel would first monitor Basin F site conditions, then would proceed to the complaint location to monitor conditions there. Odor response monitoring continued from August 5, 1988 through May 5, 1989. The odor response program terminated with the covering of Pond A.

In addition to the odor response program, an ambient odor sampling effort, the Odor Program, was set up. This program was originally under the Remedial Investigation/Feasibility Study to address odor concerns, but included support from both the Basin F remedial action contractor and the RMA Comprehensive Monitoring Program. This effort was conducted from October 21, 1988 through May 5, 1989 in an to attempt to characterize the chemical constituents of the odors. The locations of the sampling sites RIFS1 and RIFS2 are depicted in Figure 2.2-2. The site RIFS1 was at the northwest RMA boundary and the site RIFS2 was off-post just to the north of the RMA boundary.



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Figure 2.2-2

CMP Air Quality Monitoring Locations and
Meteorological Towers and Odor Program Sites

Sampling for VOCs and SVOCs began on October 21, 1988 at RIFS1, and sampling for the remaining target compounds began at both sites on December 15, 1988. The sampling strategy was similar to the Basin F strategy, in that only selected samples were submitted for analysis. These were the samples from the periods with the predicted maximum impacts. At RIFS1, sampling was conducted on all work days, and the two sample events in each week with the projected maximum impacts from Basin F emissions were analyzed. At RIFS2, one sample per week was selected for analysis. The sampled days were not always the same as the days selected for analysis of the Basin F samples. Laboratory analytical methods for this effort were identical to those of the IRA-F program (see Section 3 for details).

The results of this effort, for each group of target analytes, are presented in Section 4. These results were used to analyze and compare results from other programs and to establish impacts and trends of the ambient concentrations.

2.2.4 Comprehensive Monitoring Program

The CMP at RMA has been projected as a long-term environmental monitoring program to assess environmental conditions at RMA and to ascertain how or if these conditions might be affected by remedial activity. Part of the CMP is an air quality monitoring element. The CMP air quality monitoring includes sampling for target compounds similar to those identified for the preceding programs (VOCs, SVOCs, OCPs, TSP, PM-10, metals, asbestos). A meteorological monitoring system and a continuous air monitoring site provide additional information. The continuous air monitoring program records ambient air readings of sulfur dioxide (SO₂), nitrogen oxides (NO_x), nitric oxide (NO), nitrogen dioxide (NO₂), carbon monoxide (CO), and ozone (O₃).

The CMP air sampling program began in March 1988 and included sample collection at up to 12 sites spread across RMA. These sites are identified as "AQ" sites in Figure 2.2-2. Five of the sites are located on the RMA boundary, and the others are located at interior sites near potential sources. Mobile or portable sampling sites are also used by the CMP for special high

event sampling. The program was suspended in October 1990, but resumed in January 1991. The CMP sampling strategy was revised slightly with each of the three separate awards, but there was continuity in the fundamental structure of the program. A summary table of CMP sampling frequencies and locations is provided in Table 2.2-3. The CMP results are used for comparison and supplemental information throughout this report. The full data record and analyses may be found in the CMP Air Quality Data Assessment Report for the CMP (Stollar, 1991).

The meteorological monitoring program began complete operation under CMP in February 1989. The locations of the four towers M1, M2, M3 and M4 and the continuous monitoring site (M4) are shown in Figure 2.2-2. A composite database was developed from these sites and was used in interpreting the IRA-F results. Section 3 describes the CMP meteorology program and the use of data by IRA-F. The continuous air sampling program began operation in May 1989. Hourly average readings of SO₂, NO_x, NO₂, NO, CO, and O₃ were collected. While this effort provides excellent background air quality data for the pollutants which have traditionally been regulated as products of combustion, the data do not address impacts of Basin F remediation or other Basin F activities.

The CMP ambient air quality data are particularly relevant to interpretation of the IRA-F results due to the similarity of analytes and sampling periods of both programs. Both programs followed the established EPA six-day sampling schedule. The CMP also included sampling at mobile sites, which have from time to time been located near Basin F. In many ways, the CMP and IRA-F efforts have complemented one another, enhancing the overall spatial and temporal coverage for similar analytes. The results of the CMP are compared to and used to supplement the IRA-F results in Section 4.

2.3 REGIONAL AND LOCAL METEOROLOGICAL CHARACTERISTICS

The locality of RMA is generally classified as having a mid-latitude and semiarid climate with hot summers, cold winters and relatively light rainfall. Tables 2.3-1 through 2.3-4 provide summaries of meteorological and climatological data in the RMA vicinity. Data were collected

Table 2.2-3 Parameters and Strategies for CMP Air Monitoring Program

Parameter	Type of Sampling	Frequency	Season	Sample Locations	No. of Samples Per Year	No. of Blanks Per Year	No. of Collocated ^a Samples Per Year
TSP	Baseline	Every 6th day	All	AQ1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 and one portable station	732		61
PM-10	Baseline	Every 6th day	All	AQ1, 2, 3, 5, 9, 10 ^f	309		61
Asbestos	Baseline	Every 12th days	All	AQ1, 6, 8, 12	124	62 ^b	
VOC	Baseline	Once per season	Fall, winter, spring	AQ1, 3, 4, 5	12	3	3
SVOC	Baseline	Once per season	Fall, winter, spring	AQ1, 3, 4, 5	12	10 ^c	3
Metals	Baseline	Every 6th day	All	AQ3, 5	122	61	61
Arsenic	Baseline	Every 6th day	All	AQ3, 5	122	61	12 ^d
OCP (formerly OTSP)	Baseline	Every 12th day	All	AQ1, 3, 5	92	24	12 ^d
VOC	High event	6 high event days	Late spring, summer, early fall	AQ1, 3, 4, 5, and four mobile monitoring locations	48	6	6
SVOC	High event	6 high event days	Late spring, summer, early fall	AQ1, 3, 4, 5, or other fixed and mobile stations as appropriate	24	13 ^e	6
Metals	High event	12 high event day (approx. once/month)	All	AQ1, 3, 4, 5 and four mobile monitoring locations per sampling event	96	12	12
Arsenic	High event	12 high event day (approx. once/month)	All	AQ1, 3, 4, 5 and four mobile monitoring locations per sampling event	96	12	12
Mercury	High event	12 high event day (approx. once/month)	All	AQ1, 3, 4, 5 and four mobile monitoring locations per sampling event	96	12	24
Air Quality ^e	Baseline	Continuous	All	M4	8760 hourly averages		

Source: R.L. Stollar & Associates, Inc., 1991.

^a TSP, PM-10, SVOC, OTSP collocated samples were collected at AQ5. Collocated samples for other parameters were located with respect to suspected contaminant source proximity and logistical suitability.

^b Two blanks per sample day.

^c Includes collection efficiency spike samples with collocated background samples plus associated blank (1 ea.)

^d Approximately one-tenth of sample events will incorporate collocated sampling.

^e Includes monitoring of ozone, carbon monoxide, sulfur dioxide, nitric oxide, nitrogen dioxide, and nitrogen oxides.

^f Additional site added on September 5, 1990.

^g Sampled every 12th day through January, 1990; once per month thereafter.

TABLE 2.3-1 Summary of Temperature Data in the RMA Vicinity

	Temperatures										
	Normal ¹			Extreme ²			Maximum				
	Daily Maximum	Daily Minimum	Monthly	Record Highest	Year	Record Lowest	Year	90°F & above		32°F & below	
								23 ³	23 ³	32°F & below	0°F & below
January	43.1	15.9	29.5	49 ³	1982	-25	1963	0	7	30	4
February	46.9	20.2	33.6	73	1963	-30	1936	0	4	26	2
March	51.2	24.7	38.0	76	1971	-11	1943	0	3	25	1
April	61.0	33.7	47.4	84	1960	-2	1975	0	-	12	-
May	70.7	43.6	57.2	85	1942	22	1954	-	0	2	0
June	81.6	52.4	67.0	96	1936	30	1951	6	0	0	0
July	88.0	58.7	73.3	104	1939	43	1972	15	0	0	0
August	85.8	57.0	71.4	101	1938	41	1964	9	0	0	0
September	77.5	47.7	62.6	97	1960	20	1971	2	0	1	0
October	66.8	36.9	51.9	88	1947	3	1969	0	-	8	-
November	52.4	25.1	38.7	79	1941	-8	1950	0	2	24	-
December	46.1	18.9	32.6	75	1980	-21	1983	0	5	29	3
Annual	64.3	36.2	50.3	104	July 1939	-30	Feb. 1936	33	22	158	9

Source: ESE, Air Remedial Investigation, Draft Final Report, Vol. 1, version 2.1, May, 1988.

- 1 Normal - based on record for the 1951-1980 period.
- 2 Extreme - length of record may be for other than complete or consecutive data years. Data is the most recent in cases of multiple occurrences.
- 3 Number of years in record.

TABLE 2.3-3 Summary of Wind and Pressure Data in the RMA Vicinity

Month	Wind				Average Station	
	Through 1968		Fastest Mile ¹		Pressure in. Hg	Elevation 5,332 ft msl
	Mean Speed (mph) ²	Prevailing Direction	Speed (mph)	Direction		
	35 ³	15 ³	31 ³	31 ³		11 ³
January	8.8	S	53	N		24.63
February	9.1	S	49	NW	1976	24.63
March	9.9	S	53	NW	1953	24.54
April	10.2	S	56	NW	1952	24.60
May	9.4	S	54	SE	1960	24.63
June	9.0	S	47	S	1978	24.69
July	8.4	S	56	SW	1956	24.77
August	8.1	S	42	N	1965	24.77
September	8.1	S	47	NW	1978	24.76
October	8.0	S	45	NW	1955	24.74
November	8.5	S	48	W	1958	24.67
December	8.8	S	51	NE	1962	24.64
					1953	
Annual	8.8	S	56	SW	July 1965	24.68

Source: ESE, Air Remedial Investigation, Draft Final Report, Vol. 1, version 2.1, May, 1988.

- 1 Fastest Mile Wind -- speed is fastest observed in 1-minute value when direction is in tens of degrees. Fastest mile winds are through August 1981.
- 2 Means and extremes above are from existing and comparable exposures. Area extremes have been exceeded at other sites in the locality as follows: wind - fastest mile = 65 W in May 1933.
- 3 Number of years in record, through the current year unless otherwise noted, based on January data.

TABLE 2.3-4 Summary of Meteorological Data in the RMA Vicinity

Month	Percent of Possible Sunshine	Mean Sky Cover, Sunrise to Sunset (in tenths)	Mean Number of Days					Snow, Ice Pellets 1.0 inch or More	Thunderstorms	Heavy Fog, Visibility 1/4 mile or Less
			Sunrise to Sunset		Precipitation 0.01 inch or More	Cloudy	Partly Cloudy			
			Clear	Cloudy						
	34 ¹	35 ¹	49 ¹	49 ¹	49 ¹	49 ¹	49 ¹	43 ¹	43 ¹	
January	72	5.6	10	9	12	6	2	0	1	
February	71	5.9	8	8	12	6	2	-	2	
March	70	6.1	8	10	13	9	4	-	1	
April	68	6.0	7	11	12	9	3	1	1	
May	64	6.3	6	12	13	11	T ²	6	1	
June	71	5.0	10	12	8	9	0	10	-	
July	72	4.9	9	16	6	9	0	11	-	
August	72	4.9	10	14	7	9	0	8	1	
September	75	4.3	13	10	7	6	-	3	1	
October	73	4.5	13	10	8	5	1	1	1	
November	65	5.4	10	10	10	5	2	-	1	
December	67	5.4	11	9	11	5	2	0	1	
Annual	70	5.4	115	131	119	88	18	41	10	

Source: ESE, Air Remedial Investigation, Draft Final Report, Vol. 1, version 2.1, May, 1988.

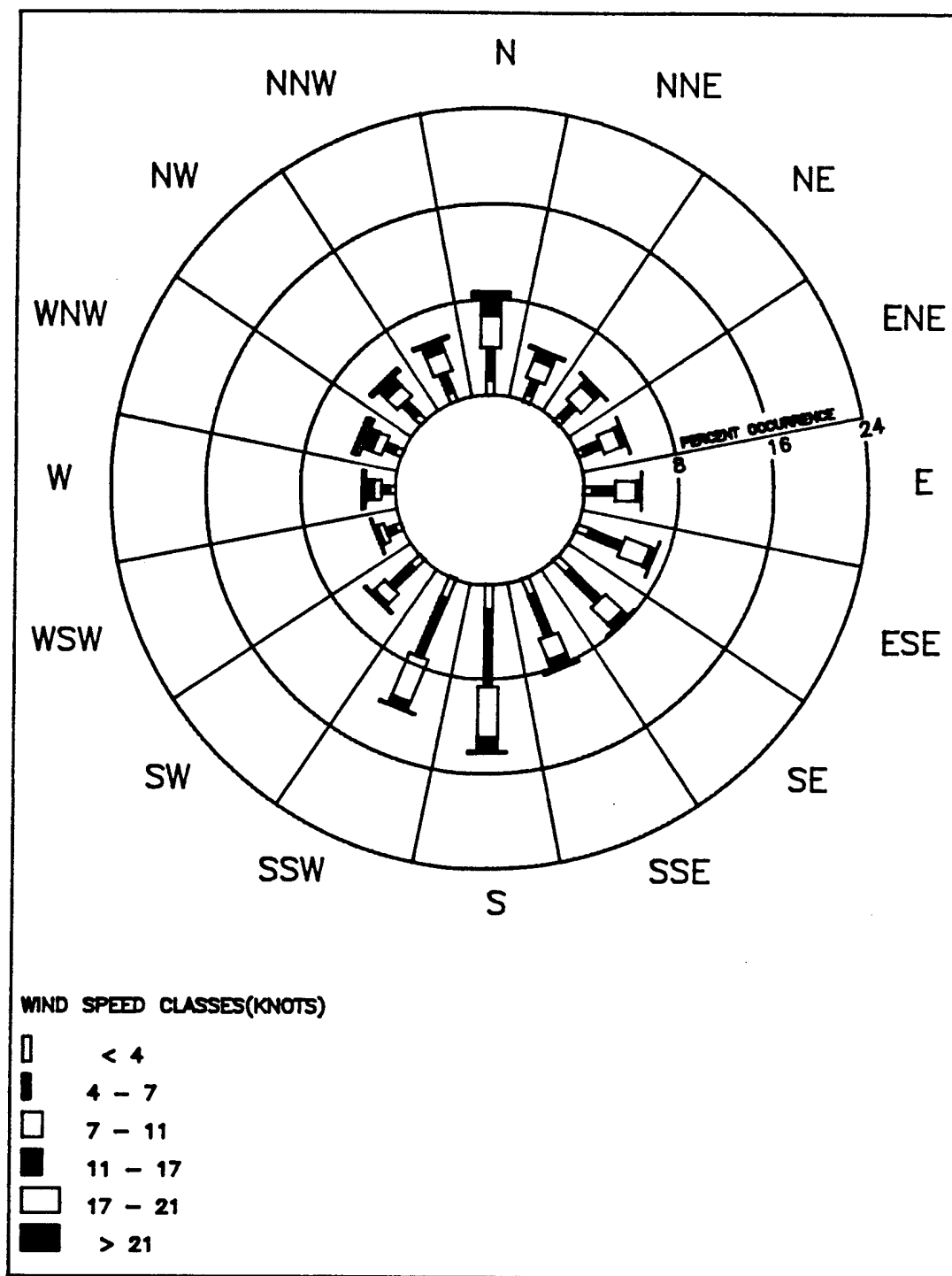
1 Number of years in record, based on January data

2 T = Less than 0.5 inch

during the IRA-F period at both RMA and Stapleton International Airport (Stapleton), which is immediately adjacent to RMA on its southern boundary. Because of the close proximity and relative uniformity of the topography between Stapleton and RMA, Stapleton's long-term climatological and meteorological conditions are presumed to be representative of RMA's long-term conditions. The RMA on-site database was used for data interpretation and atmospheric dispersion modeling in this report.

The mean maximum temperatures for the Denver metropolitan area range from 43 degrees Fahrenheit (°F) in January to 88°F in July. The mean minimum temperatures are 16°F in February and 59°F in July. Precipitation in the general region ranges from 12 to 16 inches per year, with approximately 80 percent falling as rain between April and September. Snow and sleet usually occur from September to May, with the heaviest snowfalls in March, and trace accumulations possible as late as June. Thunderstorms occur frequently in the region during the summer months, and generally bring brief rain showers, gusty winds and lightning. These storms are occasionally accompanied by heavy showers, severe gusty winds, hail and the possibility of tornadoes.

Wind directional frequencies reflect the drainage pattern of the South Platte River Valley, which slopes gradually downward from south to north. Typically, surface winds in the area flow downslope (south to north) during the night and upslope (north to south) during the daytime, resulting in a north-south bimodal distribution. This back-and-forth drainage flow is referred to as diurnal drainage flow. Figure 2.3-1 illustrates a wind rose for the RMA vicinity that reflects the north to south and south to north drainage flow. Because RMA is on higher terrain than the South Platte River Valley to the west, there is also a moderate easterly component to the drainage flow especially under very light winds and strong inversion conditions. Winds from all directions will occur under varying synoptic conditions. The windy months are March and April, with recorded gusts as high as 56 miles per hour (mph). The strongest persistent winds and the gusty winds generally come from the north to the northwest. These windy months immediately follow



Prepared for U.S. Army
Program Manager for
Rocky Mountain Arsenal

Prepared by:
Ebasco Services Incorporated

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Figure 2.3-1

**Stapleton International Airport
Wind Direction Rose (1982-1986)**

the driest months of November through February, and therefore have the highest potential for dust storms.

During recent years, the Denver metropolitan area has experienced an air pollution problem which, to a large extent, is worsened by local meteorological conditions. Early morning inversions over the Denver metropolitan area are common and they occasionally persist throughout the day. The stable atmospheric conditions of inversions prevent mixing of the atmospheric boundary layer and cause the accumulation of pollutants in the lower air layer. During nearly 60 percent of the year Denver can experience the inversions that favor air pollution accumulation. The most intense pollution events commonly occur during the winter months of December to March.

Another factor which contributes to high air pollution levels in Denver is the diurnal drainage flow. As noted, the metropolitan area is in the South Platte River basin, which is characterized by decreasing elevation toward the north and northeast. Cold, heavy air drains downslope at night and during the early morning hours. As the atmosphere warms during the afternoon, the flow reverses sharply, and much of the air which traversed the city earlier as clean air re-enters Denver as polluted air moving upslope.

2.4 REGIONAL AND LOCAL AIR QUALITY CHARACTERISTICS

The Denver metropolitan area has experienced chronic air quality problems in recent years. During stagnant and/or temperature inversion conditions, ozone and carbon monoxide concentrations sometimes create extremely poor air quality. This problem has generally been associated with motor vehicles, although air pollution also comes from a wide variety of industrial sources located in the Denver metropolitan area. Major point sources include power plants, oil refineries and transfer stations, chemical plants, cement plants and various agricultural operations. In addition to these sources, substantial emissions occur as a result of woodburning. The majority of background air quality information for criteria pollutants contained in this section was provided by CDH (CDH, 1984; 1985; 1986; 1987; 1988; 1989; 1990).

A more detailed discussion is provided in the following sections on the status of criteria pollutants, those airborne contaminants for which the EPA has established National Ambient Air Quality Standards (NAAQS) for the Denver metropolitan area and the RMA vicinity. Table 2.4-1 lists applicable standards. Data collected in the Denver metropolitan area during the IRA-F program have been obtained from CDH and are considered in the assessment sections of this report.

2.4.1 Particulates

Particulate matter in the atmosphere is a major contributing factor to health- and visibility-related problems in both urban and rural areas. In Denver, this contributes to the condition commonly known as the "brown cloud," or more appropriately the "Denver haze," because it is frequently not brown, nor is it actually a cloud. The sources of particulates are many: windblown dust and sand from roadways, fields and construction sites, coal dust, fly ash and carbon particles from various combustion sources, including automobile exhaust. Two additional particulate sources that have major impact on haze problems are diesel automobiles and wood burning stoves. These sources emit potentially significant amounts of elemental and organic carbon particles that play a major role in haze phenomena and contribute to adverse health effects. Airborne particulate matter is sampled in two separate categories. Particulates which include all particles regardless of size or TSP, and respirable particles or PM-10.

In the Denver metropolitan area, a total of 12 monitoring locations have been established for monitoring particulates. All sites are used to sample for PM-10, and five are used to sample for TSP. Not all of the sites have sufficiently complete recovery to establish a good overall database, however. The major area of concern for particulates is central Denver, which showed violations of the TSP 24-hour standard in 1989 at two sites and a violation of the PM-10 24-hour standard at the CAMP site, on Broadway at 21st Street. Through September 1990, there were violations of the 24-hour TSP standard in downtown Denver as well. The PM-10 standards were not violated through that time period.

Table 2.4-1 National Ambient Air Quality Standards

Pollutant	Averaging Time	Concentration
Particulates (TSP)		
Primary	Annual Geometric Mean	75 $\mu\text{g}/\text{m}^3$
Secondary	Annual Geometric Mean	60 $\mu\text{g}/\text{m}^3$
Primary	24-Hour ¹	260 $\mu\text{g}/\text{m}^3$
Secondary	24-Hour ¹	150 $\mu\text{g}/\text{m}^3$
Particulates (PM-10)		
Primary	Annual Arithmetic Mean	50 $\mu\text{g}/\text{m}^3$
Primary	24-Hour	150 $\mu\text{g}/\text{m}^3$
Lead (Pb)	Month ²	1.5 $\mu\text{g}/\text{m}^3$
Carbon Monoxide		
Primary	1-Hour ¹	35 ppm (40 $\mu\text{g}/\text{m}^3$)
Primary	8-Hour ¹	9 ppm (40 $\mu\text{g}/\text{m}^3$)
Ozone		
Primary	1-Hour ³	0.12 ppm (235 $\mu\text{g}/\text{m}^3$)
Nitrogen Dioxide		
Primary	Annual Arithmetic Mean	0.053 ppm (100 $\mu\text{g}/\text{m}^3$)
Secondary	Annual Arithmetic Mean	0.053 ppm (100 $\mu\text{g}/\text{m}^3$)
Sulfur Dioxide		
Primary	Annual Arithmetic Mean	0.03 ppm (80 $\mu\text{g}/\text{m}^3$)
Primary	24-Hour ¹	0.14 ppm (365 $\mu\text{g}/\text{m}^3$)
Secondary	3-Hour ¹	0.5 ppm (1300 $\mu\text{g}/\text{m}^3$)

ppm = Parts per Million

$\mu\text{g}/\text{m}^3$ = Micrograms per Cubic Meter

Source: Colorado Department of Health (1983)

- 1 Not to be exceeded more than once per year.
- 2 For Colorado Standards the averaging time is one month, for the National Standards the averaging time is a calendar quarter.
- 3 Statistically estimated number of days with exceedances, averaged over a 3 year period, is not to be more than 1 day per year.

Historical data for Denver from 1974 to 1984, in the vicinity of RMA show an average TSP value of $97 \mu\text{g}/\text{m}^3$. Studies conducted at the RMA boundary by the Army in 1969, showed a 24-hour maximum value of $274 \mu\text{g}/\text{m}^3$ and annual geometric means ranging from 24 to $72 \mu\text{g}/\text{m}^3$ (USAEHA, 1969).

Monitoring for TSP, as part of the Air Remedial Investigation Program, was conducted by Environmental Science and Engineering, Inc. (ESE) at 12 fixed sampling stations within RMA from June 1986 to June 1987 (ESE, 1988). The data collected at all sites were in compliance with both the primary and secondary NAAQS with the exception of one 24-hour sample near South Plants. This sample was $151 \mu\text{g}/\text{m}^3$, compared to the 24-hour secondary standard of $150 \mu\text{g}/\text{m}^3$. The highest annual average TSP level was $55 \mu\text{g}/\text{m}^3$ at the west boundary, while the lowest was $34 \mu\text{g}/\text{m}^3$ at the interior of the Arsenal. During Phase 1, TSP levels were comparable to the RI results, with the exception of monitoring sites adjacent to Basin F and earthmoving efforts. These sites, on occasion, reached 24-hour maximum levels of 500 to $600 \mu\text{g}/\text{m}^3$. As noted in previous reports, these high levels decreased rapidly with distance from the ground disturbances. Higher TSP levels in the vicinity of Basin F continued until vegetative ground cover was put in place, and landscaping activities were concluded in May 1989. The relatively low particulates levels continued until the termination of the IRA-F program. A detailed discussion of TSP results is presented in Section 4.1.

During 1989, the highest PM-10 levels in the Denver metropolitan area were reported at the downtown Denver CAMP location; the 24-hour PM-10 concentration was $154 \mu\text{g}/\text{m}^3$ and the maximum annual average was $42 \mu\text{g}/\text{m}^3$ (48th Street station). Respirable particulates concentrations for Denver through September 1990 indicated a maximum PM-10 level of $118 \mu\text{g}/\text{m}^3$ during January, with several downtown readings in excess of $100 \mu\text{g}/\text{m}^3$. It is noted that high 24-hour TSP levels also occurred during these same events both in the Denver metropolitan area and at RMA, and were most likely attributable to intense inversion conditions on the sampling days.

Levels of PM-10 were monitored during the 1986 to 1987 RI program at three air quality sampling stations: two at RMA boundaries and one within RMA. Levels of PM-10 were highest at the boundary stations and lowest at the interior station. The arithmetic mean values ranged from 18 $\mu\text{g}/\text{m}^3$ at the interior (near Basin A) to 36 $\mu\text{g}/\text{m}^3$ at the northwest boundary. Individual 24-hour values ranged from 5 to 94 $\mu\text{g}/\text{m}^3$, with lower levels at the RMA interior and the higher levels at its boundary. The elevated PM-10 levels were also attributable to Denver's brown cloud conditions. Detailed results of PM-10 sampling are discussed in Section 4.2.

2.4.2 Metals

Airborne metals, which exist primarily as particulate matter, may be inhaled and can cause adverse health effects. One of these metals is lead, which is primarily produced from the combustion of leaded gasoline in passenger vehicles. Lead is the only metal that is an EPA criteria pollutant. The current federal standard for lead is 1.5 $\mu\text{g}/\text{m}^3$ for a 3-month (calendar quarter) average concentration. The Colorado standard is 1.5 $\mu\text{g}/\text{m}^3$ averaged over a 1-month data period (CDH, 1983). Lead values have decreased steadily in the Denver metropolitan area over the past decade. Maximum quarterly levels have decreased from in excess of 1.5 $\mu\text{g}/\text{m}^3$ in the 1970s to less than 0.08 $\mu\text{g}/\text{m}^3$ in 1989 (CDH, 1984; 1985; 1986; 1987; 1989; 1990).

Historical data for lead in the vicinity of RMA indicate concentrations of 0.5 to 1.0 $\mu\text{g}/\text{m}^3$, but a significant decline has been recorded during the last 10 years with the introduction of lead-free gasoline. The Army monitored RMA lead concentrations at the boundaries and interior in 1980. The average concentrations ranged from 0.13 to 0.26 $\mu\text{g}/\text{m}^3$ (USAEHA, 1981). Lead and other metals were monitored during the 1986 to 1987 RI program (ESE, 1988). High event samples were taken on high wind days at approximately 10 locations. Lead values were generally less than 1.0 $\mu\text{g}/\text{m}^3$ and were consistent with typical urban values. Other metals (mercury, arsenic, cadmium, chromium, copper and zinc) were also detected at typical urban concentrations, with slightly elevated concentrations of cadmium (up to 0.017 $\mu\text{g}/\text{m}^3$) and copper (up to 0.91 $\mu\text{g}/\text{m}^3$) near the basins. Zinc levels were typical of urban environmental levels, except for a single day when concentrations were in excess of 10 $\mu\text{g}/\text{m}^3$. The RI report states that zinc levels measured

for this day may be suspect because low levels were detected during all other events. During the Phase 1 period, metals values were consistent with previous RMA investigations with the exception of somewhat higher levels of copper, chromium, mercury and zinc in the immediate vicinity of the Basin F cleanup work. However, these levels dropped significantly at the conclusion of remedial activities during Fiscal Year 1989 (FY89) and continued to decrease during FY90. Results of metals sampling are discussed in Section 4.3

2.4.3 Gaseous Pollutants

Gaseous criteria pollutants monitored by the CMP are those listed in the National Ambient Air Quality Standards summarized in Table 2.4-1. These gaseous pollutants are also monitored by CDH at nine sites in the Denver metropolitan area. Of these sites, the levels measured at the CDH Welby site (78th and Steele) were most relevant to RMA. Levels measured in downtown Denver at the CDH CAMP site were also interesting for comparison. As recently as 1987, all Denver sites showed exceedences of the 8-hour secondary maximum standard for carbon monoxide. At the Welby site in 1989, there were no exceedences, but at the CAMP site there were six. This level of violation was considerably below the 30 or so annual violations recorded through 1984, indicating an overall improvement in the Denver area air quality.

Ozone levels in Denver have also been a major concern. At Welby, there were exceedences of the ozone standard in 1983, 1985 and 1986, but no violations in subsequent years. At the CAMP site, the last exceedence of the ozone standard occurred in 1983. Although Denver has not had any recent violations of the ozone standard, it still is technically classified as an ozone nonattainment area. Colorado is likely to petition for a change in status if ozone levels remain below the standards.

For nitrogen dioxide a single annual average standard of 0.053 parts per million (ppm), is in effect. The 1989 annual average for this compound at the CAMP site was 0.039 ppm, and at the Welby site, it was 0.018 ppm. Levels at the CAMP site have decreased somewhat in recent years (the 1978 annual average was slightly above the standard), but they have remained fairly constant

at the Welby site since data collection began in 1976. Sulfur dioxide is also measured at CAMP and Welby, and both the short-term and annual average levels have been well below standards.

3.0 PROGRAM STRATEGY AND METHODOLOGY

The purpose of the IRA-F air monitoring program at RMA has been to continue the collection of air quality data at sites in close proximity to the remediated Basin F area, to characterize air quality conditions and to document the baseline post-remediation air quality. The sampling effort began after closure of the Basin F remedial activities, and it combined the methods of the precursor ambient Odor Program sampling and Basin F air monitoring project. The IRA-F sampling period extended from May 1989 through September 1990, and included sampling at seven sites during the first two months of the program, and five sites during the remainder of the program. In addition, monitoring was conducted to sample emissions from the waste pile cap and vents, the restored Basin F floor, the liquid storage pond north of the restored basin, and the storage tanks northeast of the restored basin.

The IRA-F program provided complete analyses of the ambient air samples and special emissions samples along with evaluation and analyses of the reported results. Comparisons of these data to the findings of other programs have been provided in this report. This effort involved data processing activities and QA of the collected data. It also involved the identification of any trends and identification of any concerns relating to air quality conditions near Basin F. A comparison to health-based standards or acceptable ambient concentrations was also conducted, and the results are presented in Section 6.

The IRA-F sampling program has been coordinated with the CMP. Meteorological data collected by the concurrent CMP were used by the IRA-F program in calculating sample volumes and to evaluate results. No independent meteorological monitoring has been performed under the IRA-F project.

3.1 GENERAL BACKGROUND

Of critical importance in the IRA-F program was the development and use of a list of target compounds, or compounds which were the focus of laboratory analyses. These compounds were of concern around the Basin F area. Analyses for nontarget compounds, or chemical compounds

not on the target list, were conducted on selected regular samples. The list of target compounds, or target analytes, were developed from preceding air quality programs at RMA, and from earlier investigations that focused on potential air quality concerns (WES, 1982) and U.S. Army Environmental Hygiene Agency tests to monitor emissions from Basin F (USAHEA, 1982). The list of target analytes is provided in Table 3.1-1. The analytes can be grouped into several categories, as indicated in the table. The grouping is based on both the sampling technique and the laboratory analytical procedures. In addition, both VOC and SVOC samples were analyzed for selected nontarget compounds. The IRA-F project has used a combination of sampling techniques to collect data from sites within and surrounding the remediated Basin F. Analytes measured throughout the IRA-F project have included TSP, PM-10, VOCs, SVOCs/OCPs, mercury, ICAP metals (cadmium, chromium, copper, lead and zinc) and arsenic. These analytes were collected by standard EPA approved ambient air sampling methods which are described in detail in Section 3. The sampling network included, during different phases, between six and 10 TSP samplers, two PM-10 samplers, 11 mercury samplers, nine VOC samplers and nine SVOC/OCP samplers.

The Basin F network was designed specifically to evaluate impacts surrounding the remedial activity during and after cleanup operations. Due to the anticipated changes in ambient air quality during and after the active period of the Basin F cleanup, the analytical results of air quality sampling were divided into phases. These phases were defined by the scope and magnitude of remedial activity during each segment of the operation. Phase 1 encompassed the period from the start of remedial activities on March 22, 1988 until all intrusive remedial activities had ceased on the Basin F floor December 12, 1988. Phase 2 was divided into Stage 1 and Stage 2. During Stage 1 the installation of the first clay cap on the Basin F floor and the final construction work on the waste pile were completed (December 13, 1988 through February 15, 1989). By the end of Stage 1 all Basin F liquid had been contained within the storage tanks or Pond A, and thus the emission source was greatly reduced. Stage 2 encompassed the time period from February 16, 1989 through May 5, 1989 and included completion of placement of the topsoil layers on the Basin F Floor and the waste pile cap. It was during this stage that the

Table 3.1-1 IRA-F Air Sampling Target Compounds

Target Volatile Analytes	Target Metals
Benzene	Arsenic
Bicycloheptadiene	Cadmium
Carbon tetrachloride	Chromium
Chlorobenzene	Copper
Chloroform	Lead
1,1-dichloroethane	Zinc
1,2-dichloroethane	Mercury
Dibromochloropropane	
Dicyclopentadiene	<u>Other Analytes</u>
1,2-dimethyl benzene (Ortho-xylene)	Total Suspended Particulates
Dimethyl disulfide	Respirable Particulates
Ethylbenzene	
Methyl isobutyl ketone	
Methylene chloride	
N-nitrosodimethylamine (NNDMEA)	
Tetrachloroethylene	
Toluene	
Trans-1,2-dichloroethylene	
1,1,1-trichloroethane	
1,1,2-trichloroethane	
Trichloroethylene	
Meta- and Para-Xylene	

Target Semivolatile and Organochlorine Pesticide Analytes

Aldrin *
 Atrazine
 t-Chlordane *
 Chlorophenyl methyl sulfone
 Chlorophenyl methyl sulfoxide
 p,p'-dichlorodiphenylethane *
 p,p'-dichlorodiphenyltrichloroethane *
 Dieldrin *
 Endrin *
 Isodrin *
 Malathion *
 Parathion *
 Supona *

* OCP Target analyte

final grading and seeding of the Basin F area was completed and the top liner on Pond A was emplaced. Once the reclamation was complete and Pond A was sealed, the emissions sources were limited to off-gas vents on the waste pile, the Pond A vents and the storage tank vents. When Phase 2 was complete, earthmoving also ceased, so particulate emissions from handling and hauling were greatly reduced. Phase 3 encompassed the post remedial portion of Fiscal Year 1989 (FY89) (May 6, 1989 through September 30, 1989) and Phase 4 extended throughout Fiscal Year 1990 (FY90) (October 1, 1989 through September 30, 1990) and represents a complete year of post-remedial sampling. Table 3.1-2 summarizes the phases for which sampling data are available, and includes a systematic reference to applicable dates, activities and air sampling activities. Air sampling and supplemental monitoring results for the four phases are discussed in detail in Section 4.

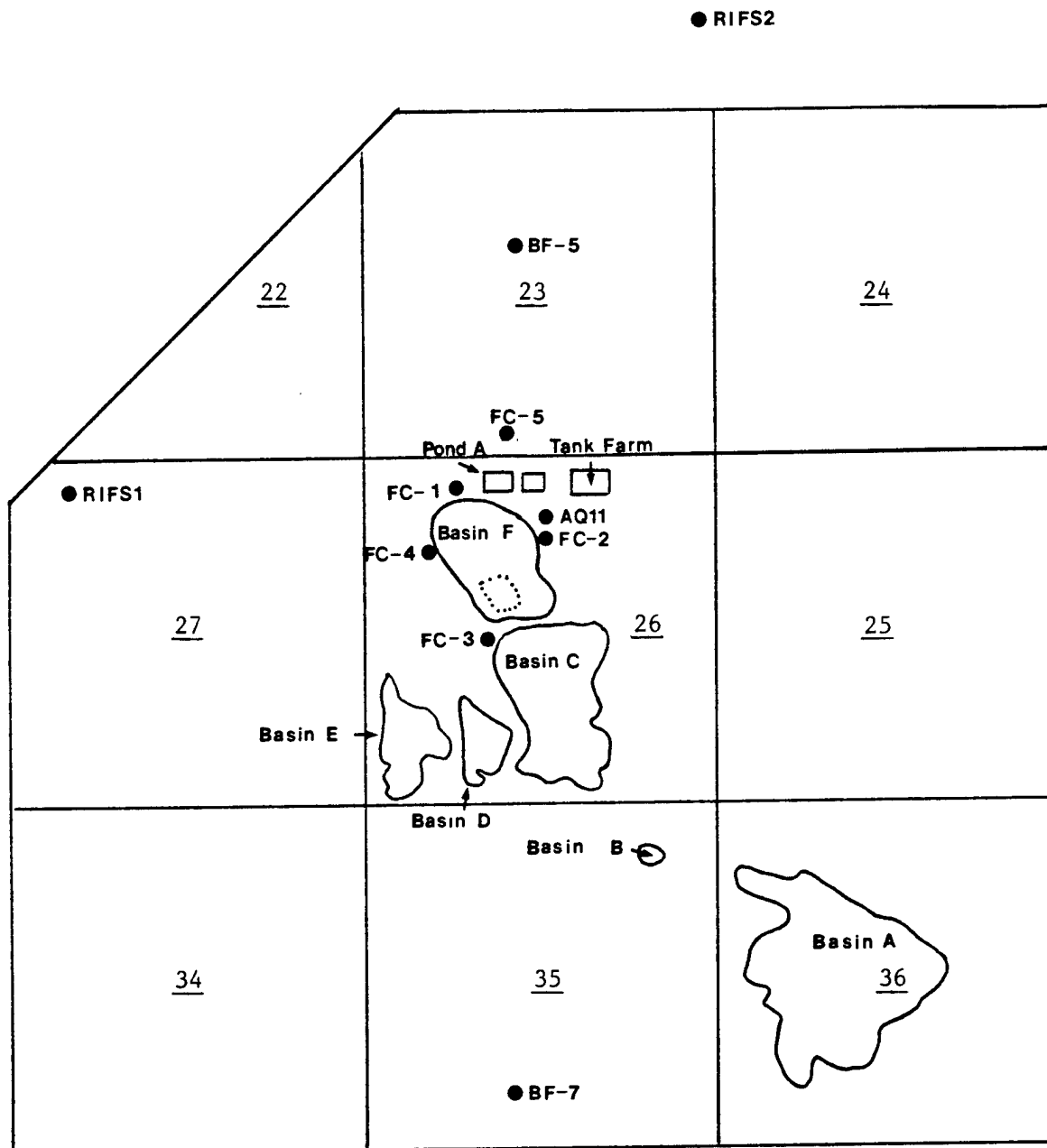
The IRA-F program's main emphasis was ambient air quality monitoring in the Basin F vicinity. Supplemental monitoring was performed to determine the potential emissions from the waste pile cap and vents, the restored Basin F floor and the liquid storage areas. The special emissions monitoring methods are discussed in Section 3.3.

The majority of the monitoring locations used by the IRA-F ambient air quality monitoring program were identical to those sites that were designated as BF sites under the Basin F air monitoring program. These sites were redesignated as "FC" sites, but retained the same number sequence that was used for the BF designations. Figure 3.1-1 illustrates the locations of the IRA-F air quality monitoring sites. The sampling results from the "BF" sites were presented in the "Basin F Interim Action Close-out Safety Report," (EBASCO, 1989) which may be used for comparison to the IRA-F data collected at identical locations. Comparisons of these data are summarized in Section 4.

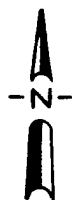
The strategy and methods used for collecting the ambient air samples are described in the following section. Also described are the data processing procedures and the quality assurance procedures used in developing the database and in certifying the data. Presented in Section 3.2

Table 3.1-2 Basin F Remediation Phases and Associated Air Sampling Programs

Phase	Dates	Activity	Associated Air Sampling Programs
1	03/22/88-12/12/88	Basin F Cleanup. Stockpiling of clay for future capping of basin.	CMP FY88, CMP FY89, Basin F Remediation Monitoring Program, Odor Program
2	12/13/88-02/15/89 (Stage 1)	Capping of basin with clay.	CMP FY89, Basin F Remediation Monitoring Program, Odor Program
	02/16/89-05/05/89 (Stage 2)	Capping of basin with topsoil. Grading and reseedling of basin and surrounding area. Liner installed over holding pond.	Same as above
3	05/06/89-09/30/89	Pumping of accumulated waste pile liquids to holding pond.	CMP FY89, IRA-F
4	10/01/89-09/30/90	No remedial activity. Pumping of accumulated wastepile liquids to holding pond.	CMP FY90, IRA-F



LEGEND
FC ● Monitoring Site



0 0.5 1
mile

Prepared for U.S. Army
Program Manager for
Rocky Mountain Arsenal

Prepared by:
Ebasco Services Incorporated

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Figure 3.1-1

IRA-F Air Quality Monitoring Locations

are sampling methodology, sampling schedules and sampling locations for Basin F ambient air. Special sampling such as waste pile cap and vent emissions sampling are described in Section 3.3. The CMP meteorology program is discussed in Section 3.4. Data processing procedures are presented in Section 3.5, and the laboratory analytical program is discussed in Section 3.6.

3.2 AMBIENT AIR QUALITY SAMPLING

Ambient air quality data were generated from samples that were collected by drawing a calculable volume of air through a collection medium and by subsequent laboratory analyses of that medium to determine the quantity of each target analyte in the sample. The atmospheric concentration was then determined by dividing the mass of analyte in the sample by the calculated volume of air sampled. Samples were collected over a target period of 24-hours, in accordance with sampling guidance provided by the EPA. All individual concentrations therefore represent average concentrations from the 24-hour sample period.

3.2.1 Sampling Methodology

A field procedures manual prepared for this program included detailed steps for sample handling, installation, removal, flow checks, shipping, integrity control and document preparation. The procedures manual is presented in Appendix A. General field procedures ensured that the sample media were kept free of all potential contaminants including food, smoke, fragrances, or volatiles of any kind. Clean cotton gloves were used when handling the sample media. Field data sheets were generated for each sampling episode. These sheets indicated the start and stop times, flow indications, weather conditions, timer indications, and media sample numbers for each site and for each analyte group. In addition, a separate chain-of-custody was generated for each sample episode. Information submitted on the chain-of-custody included the sample date, sampling site, media number and type of media, as well as analyses requested. This chain-of-custody was a critical step in the QA process for IRA-F data. Samples were shipped to the analytical laboratory in sealed containers, and a chain-of-custody record ensured uncompromised and timely arrival of samples.

For each of the analyte groups a separate sampling methodology was employed. This methodology was based on guidance provided by EPA for sampling both particulate matter and air toxics. Each group of compounds to be sampled required a separate method of collection. Generally the systems used reflected the state-of-the-art technology, approved for use by the EPA, CDH and the PMRMA. Each sampling methodology is described below.

3.2.1.1 Total Suspended Particulates

Particulate matter was collected on a fiberglass filter, using a General Metal Works Model GMW-2000H Hi-Vol sampler. Air flow was controlled by an electronic mass flow controller. The system was based on guidelines provided by EPA "Reference Method for Determination of Suspended Particulates in the Atmosphere High Volume Method" (EPA-600/4/77/027a) and Title 40 of the Code of Federal Regulations (CFR), Part 58, Appendix B.

3.2.1.2 Respirable Particulate Matter

The collection method for PM-10 was very similar to that for TSP, however, quartz filters were used for PM-10 and an aerodynamic impactor was used to separate the larger particles from those with an aerodynamic diameter of less than 10 μm . A GMW Model Accu-Vol IP-10 sampler with a Model 1200 inlet was used for PM-10 sample collection.

3.2.1.3 Arsenic and ICAP Metals

The target metals (arsenic, cadmium, chromium, copper, lead and zinc) were collected as a part of the TSP sampling effort. The collection methodology for metals followed the EPA method (40 CFR, Part 58) for lead determination. Samples were collected on fiberglass filters using the high volume sampling method described in Subsection 3.2.1.1. Following the gravimetric analysis for TSP, a portion of each TSP filter was analyzed for arsenic and ICAP metals.

3.2.1.4 Volatile Organic Compounds

Volatile organic compounds, or compounds with relatively low boiling points, were monitored using a GMW Model VOTA sampler, which was adjusted to draw air at a nominal rate of 200 standard cubic centimeters per minute (sccm) for a 24-hour period. The sampling technique was conducted in accordance with the guidelines of EPA Method T0-1 from the "Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air" (EPA-600/4-84-041). Air was drawn through a glass tube containing Tenax, followed by a separate tube containing Tenax-and-charcoal. Results from the analyses of these two tubes were used to determine the sample concentrations.

3.2.1.5 Semivolatile Organic Compounds/Organochlorine Pesticides

Organic compounds with relatively high boiling points were monitored using a high volume sampler (GMW Model PS-1) with a target flow rate of 200 liters per minute over a 24-hour period. The sampling was done in accordance with EPA Method T0-4 from "Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air" (EPA-600/4-84-041). The sampled air was drawn through a quartz pre-filter, then through a PUF plug, with collection of particulate matter on the quartz filter and adsorption of organic vapors on the PUF plug. Both the pre-filter and PUF plug were submitted to the laboratory for analysis. The same media were analyzed for both the SVOC and organochlorine pesticide (OCP) analytes.

3.2.1.6 Mercury

Mercury was collected from ambient air using a Hydrar-filled glass tube, connected to a GMW VOTA sampler, using a flow circuit separate from the one used during VOC sampling. The target flow rate was 100 sccm. Mercury was sampled on the same noon-to-noon schedule as VOCs.

3.2.2 Sampling Schedule

A sampling period of 24-hours was used for all samples. The sample days coincided with the EPA and CDH six-day schedule for sampling particulates (Figure 3.2-1). The TSP, PM-10, and metals samples were collected on alternate sampling days from midnight to midnight of the sample days. Thus, the sampling interval for particulates, metals and arsenic was twelve days. The organic compounds and mercury were collected from noon of the day prior to the scheduled sample date to noon of the scheduled sample date. The organics were sampled every sixth day, but mercury was sampled every twelfth day on the same schedule as particulates and metals. All sampling was conducted on Mountain Standard Time throughout the year.

Automatic timers were used to start and stop the TSP/metals and PM-10 samplers. The VOC, SVOC and mercury samples were started manually, shortly after the media were installed, and stopped manually, just prior to removal of the sample media. Flow checks were made four times during the sample period; at installation, twice during the sampling run and just before media removal at the end of the sample period.

3.2.3 Sampling Locations

The sampling locations shown on Figure 3.1-1 were chosen to allow characterization of maximum concentrations which might be used to project probable concentrations downwind from Basin F. The locations were selected to approximate the locations of the perimeter sites used during the Basin F remedial activity. These locations allowed further data collection from previously established points to provide continuity and tracking of trends associated with the interim action closure. During the Basin F program, these sites which had been BF-1 through BF-4 were redesignated FC-1 through FC-4.

Site FC-1, previously BF-1, was located west of Pond A near the north edge of the restored basin. Collocated sites FC-2 and FC-2D, previously BF-2 and BF-2C, were located just east of the restored basin and southeast of Pond A. Site BF-3, was moved 60 feet east from its original location and positioned atop a berm, when it was redesignated as FC-3. Site FC-4 was positioned

January 1990
 S M T W T F S
 1 2 3 4 5 6
 7 8 9 10 11 12 13
 14 15 16 17 18 19 20
 21 22 23 24 25 26 27
 28 29 30 31

February 1990
 S M T W T F S
 4 5 6 7 8 9 10
 11 12 13 14 15 16 17
 18 19 20 21 22 23 24
 25 26 27 28

March 1990
 S M T W T F S
 4 5 6 7 8 9 10
 11 12 13 14 15 16 17
 18 19 20 21 22 23 24
 25 26 27 28 29 30 31

April 1990
 S M T W T F S
 1 2 3 4 5 6 7
 8 9 10 11 12 13 14
 15 16 17 18 19 20 21
 22 23 24 25 26 27 28
 29 30

May 1990
 S M T W T F S
 1 2 3 4 5
 6 7 8 9 10 11 12
 13 14 15 16 17 18 19
 20 21 22 23 24 25 26
 27 28 29 30 31

June 1990
 S M T W T F S
 1 2
 3 4 5 6 7 8 9
 10 11 12 13 14 15 16
 17 18 19 20 21 22 23
 24 25 26 27 28 29 30

July 1990
 S M T W T F S
 1 2 3 4 5 6 7
 8 9 10 11 12 13 14
 15 16 17 18 19 20 21
 22 23 24 25 26 27 28
 29 30 31

August 1990
 S M T W T F S
 1 2 3 4
 5 6 7 8 9 10 11
 12 13 14 15 16 17 18
 19 20 21 22 23 24 25
 26 27 28 29 30 31

September 1990
 S M T W T F S
 1
 2 3 4 5 6 7 8
 9 10 11 12 13 14 15
 16 17 18 19 20 21 22
 23 24 25 26 27 28 29
 30

October 1990
 S M T W T F S
 1 2 3 4 5 6
 7 8 9 10 11 12 13
 14 15 16 17 18 19 20
 21 22 23 24 25 26 27
 28 29 30 31

November 1990
 S M T W T F S
 1 2 3
 4 5 6 7 8 9 10
 11 12 13 14 15 16 17
 18 19 20 21 22 23 24
 25 26 27 28 29 30

December 1990
 S M T W T F S
 1
 2 3 4 5 6 7 8
 9 10 11 12 13 14 15
 16 17 18 19 20 21 22
 23 24 25 26 27 28 29
 30 31

○ EPA Scheduled Sample Day

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Figure 3.2-1

EPA Six Day Air Sampling Schedule for 1990

approximately 300 feet to the east of the former site BF-4. The sampling inlet height of BF-4 was also reduced from 3 meters, which was used during the remedial activity, to the standard 2 meters. (The higher inlet level was due to air flow obstruction from a compound of contractor trailers in place during the remediation activity.) Site FC-5 was located approximately 150 feet north of Pond A. Site BF-7, was located in Section 35, approximately 1.5 miles south of Basin F. This site was used briefly during IRA-F, but was not redesignated as an FC site. The original Odor Program site RIFS1, located in the northwest corner of Section 27, was also used briefly, but was not redesignated.

At the start of the program, sampling was conducted for two months (May and June 1989) at three special sites, BF-5, BF-7, and RIFS1, as indicated on Figure 3.1-1. These samplers were located to provide more distant upwind and downwind readings for comparative estimates of plume dispersal. During June 1989 site FC-5 became operational. This site was located to provide a downwind estimate of concentrations that might be emanating from the liquid storage pond (Pond A). Sampling was conducted at FC-1 through FC-5 throughout the bulk of the program.

3.3 CAP AND VENT MONITORING

The purpose of the cap and vent monitoring effort was to characterize emissions of these particular sources to aid in assessing their possible impact on ambient air quality. Two separate methods were used in analyzing these emissions. The first involved real-time readings of total organics using both an OVA and an H-Nu. The second, companion effort involved sampling for volatile organics using evacuated, Summa passivated stainless steel canisters (EPA Method TO-14). The locations and sampling frequency are discussed below.

3.3.1 The Basin F Waste Pile Sampling

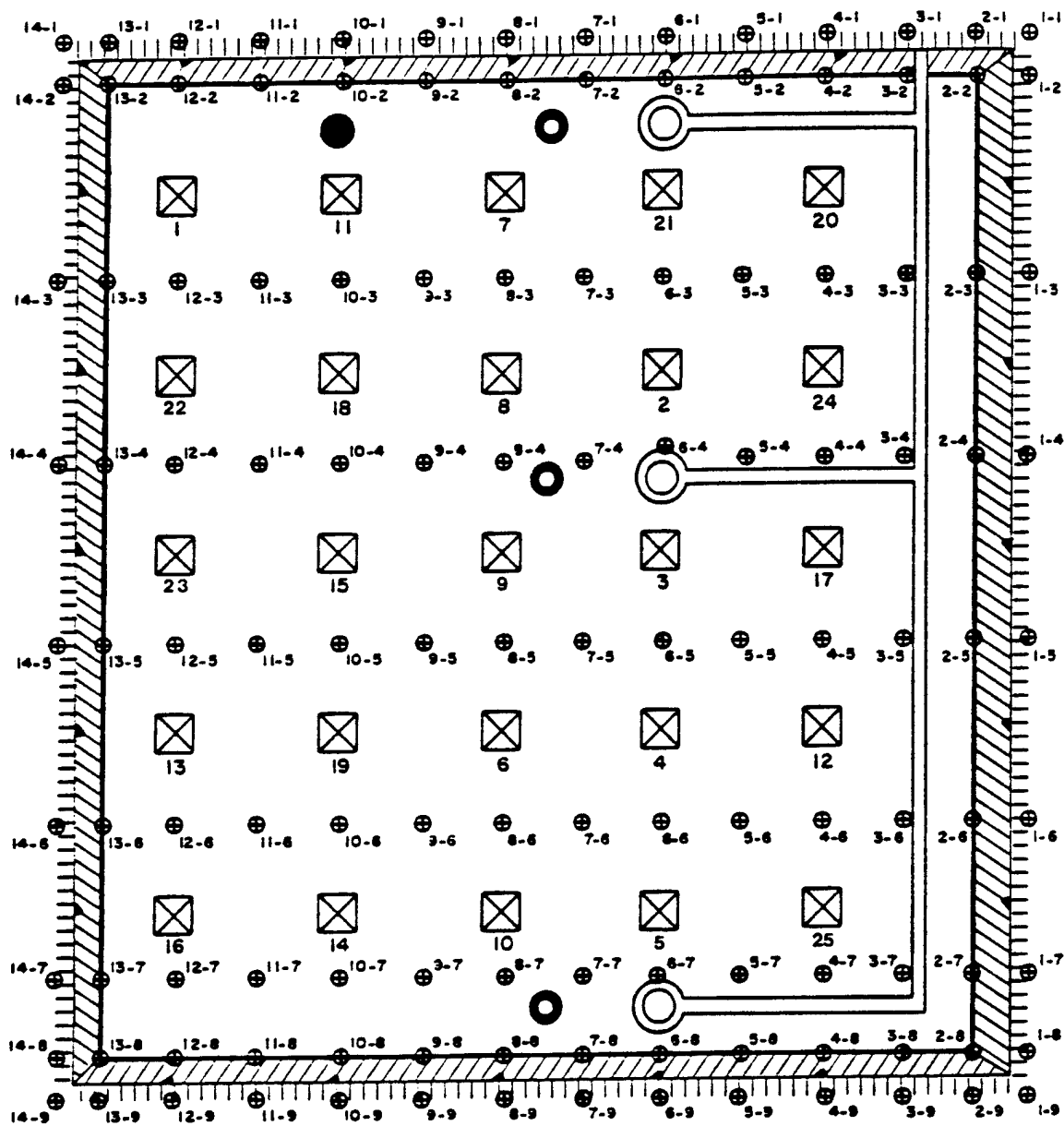
The Basin F waste pile contains a mixture of contaminated soils taken from Basin F during the remedial activity. The soils were overlain by a homogeneous high density polyethylene liner and a clay cap. The clay cap was covered with a layer of topsoil and seeded to encourage a






vegetative cover. During construction of the waste pile, a total of 25 passive off-gas release vents were installed through the liner to relieve potential air pressure gradients from recurring atmospheric pressure changes and from internal vaporization of contaminants. The vents are spaced in an irregular grid across the waste pile, as indicated in Figure 3.3-1, and the vents are numbered in a random numbering scheme. The height of each vent varies with the depth of the waste pile cap and ranges from 1 to 3 feet above the ground. Vent pipes are 6 inches in diameter and terminate in a down-curved opening. Figure 3.3-2 presents a schematic cross section of a typical waste pile vent.

Real-time monitoring of the waste pile vents took place on a monthly basis for the first four months of the program, June through September 1989. Thereafter the vent monitoring took place on a quarterly basis. Real-time monitoring consisted of readings taken at about 1 inch below the vent opening on the downwind side, during periods when winds were light (less than 10 mph) and atmospheric pressure was dropping. Readings were taken with an OVA and an HNu to sense total organics. An Extox gas monitor with colormetric indicator tubes was used to detect hydrogen sulfide, and a hand pump was used to collect indicator tube readings for ammonia. Each sample reading was taken over an approximately 30 second interval.

During each of three episodes in 1990, a set of "grab samples" was taken at selected vents. The vents selected for sampling were those that had relatively high readings of total organics during the preceding real-time monitoring. The grab sampling duration was from two to five minutes. During the initial event, the samples were taken from outside the vent openings as was done during the real-time readings. After review of the results from the first sampling episode, it was determined that more suitable data could be obtained by sampling within the vent. This method was adopted for the remaining two episodes. Samples were drawn through a sample collection tube that was inserted approximately 12 to 18 inches inside the vent.

The vent grab samples were drawn using evacuated stainless steel canisters, in accordance with EPA Method T0-14 EPA, 1984). Concurrent real-time readings were taken with OVA and HNu



- Legend**
-  Vent with Existing Vent Number
 -  Sand Bags
 -  Baseplate Standpipe
 -  Detection Sump and Baseplate Standpipe
 -  Leachate Collection Sump and Baseplate Standpipe



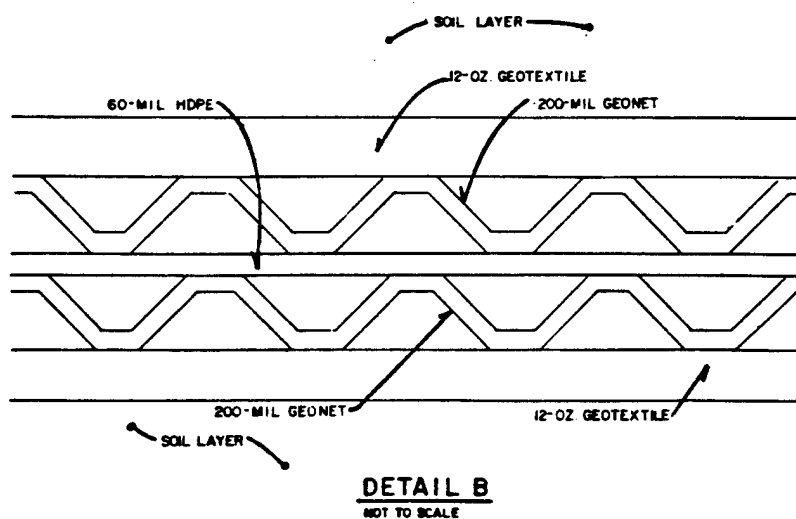
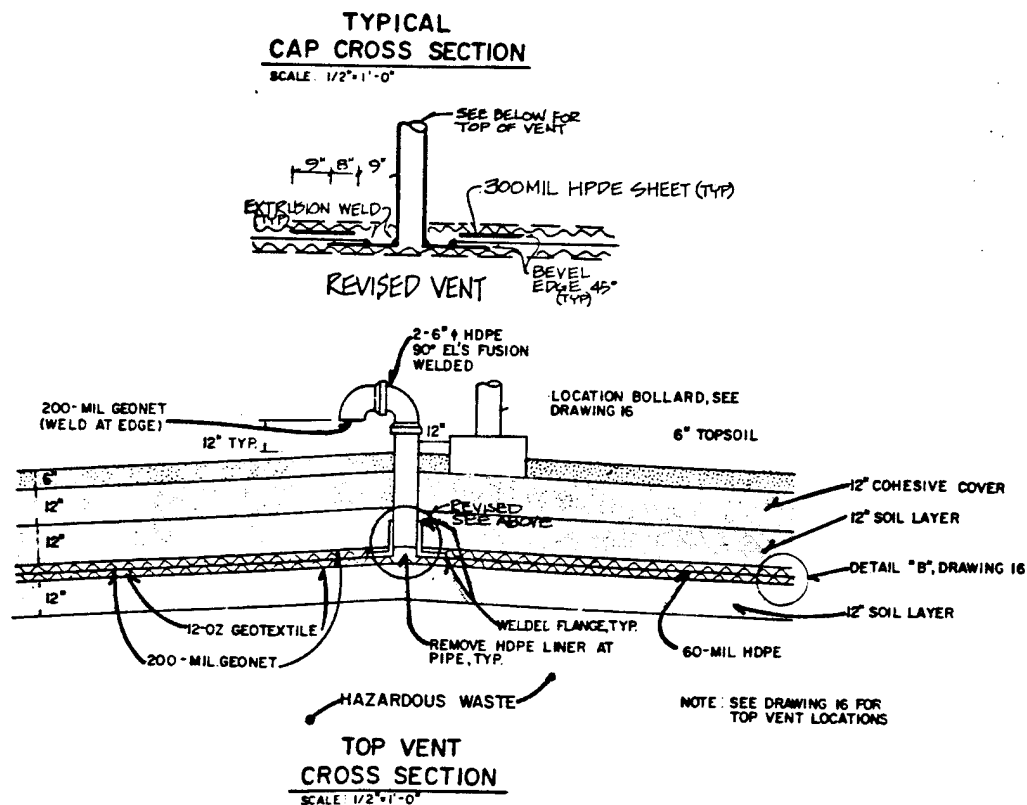
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Figure 3.3-1

**Locations of Waste Pile Vents and Sandbags
for Real-Time Monitoring**



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Figure 3.3-2

Schematic Diagram of Typical Waste Pile Vent

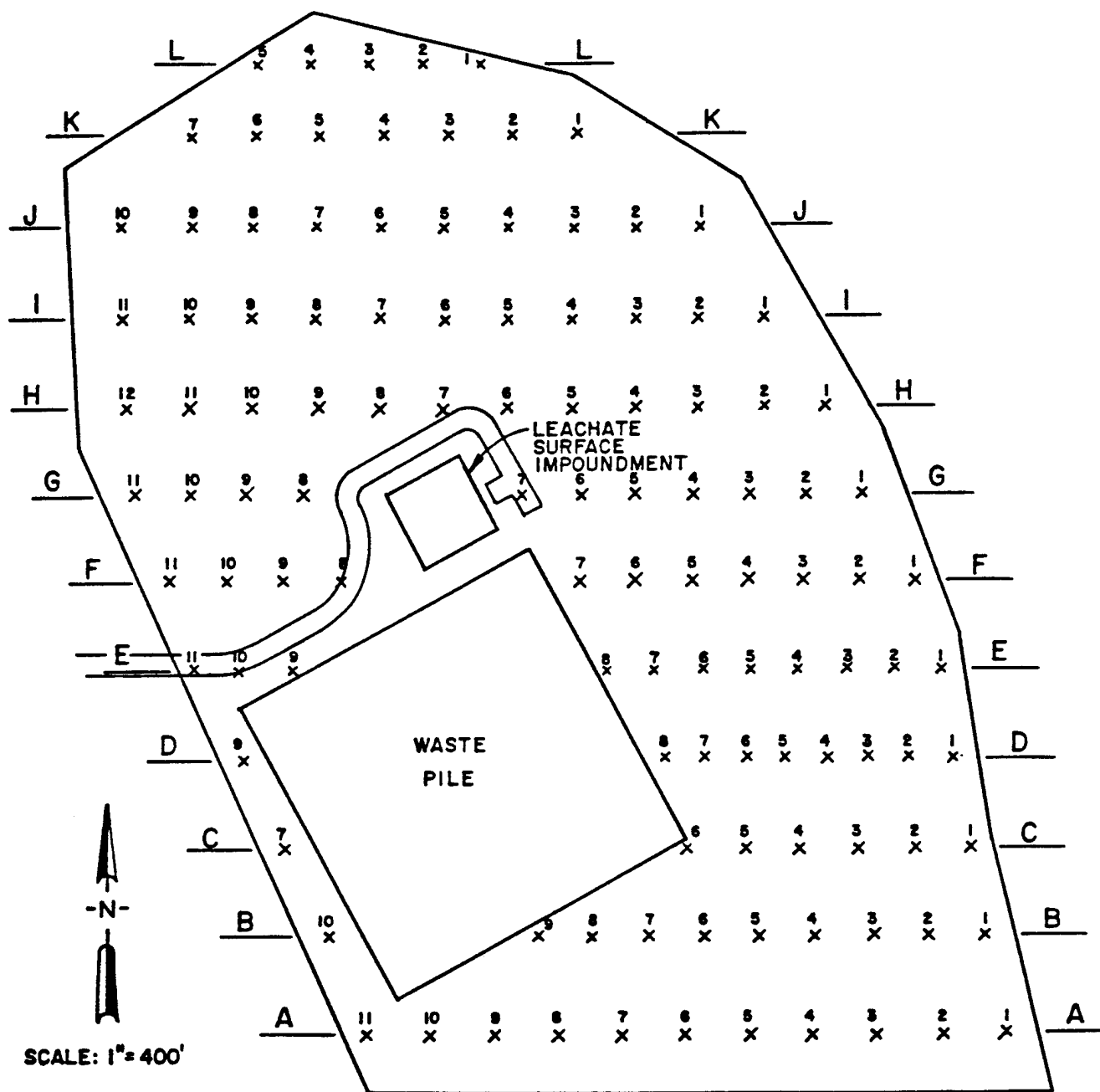
analyzers and ammonia and hydrogen sulfide colorimetric tubes. The sample durations and preliminary and final vacuum readings were recorded, and the canister samples were shipped to a laboratory for analysis. At the time the grab samples were taken, the exhalation flow rates of the vents were estimated by attaching polyethylene bags of known volume over the vents and noting the length of time that was required to fill them. Emission estimates were made for target analytes by combining the fill rate data with the grab sample concentrations provided by the laboratory.

In addition to the sampling discussed above, real-time readings of the waste pile cap surface, were taken using the OVA and the HNu. The instrument probe was fitted with an extension tube ending in a small funnel. The technician traversed the waste pile cap in a predetermined pattern and collected representative readings at a total of 126 marked locations regularly spaced across the waste pile. These locations are shown in Figure 3.3-1. The sample was drawn from approximately 1 inch above the ground at each location, and real-time readings were recorded on field data sheets. There were also three separate episodes of sampling the waste pile surface using flux chambers. These sampling efforts were conducted concurrently with the flux sampling of the Basin F floor. Details are presented in Section 3.3.2.

3.3.2 Basin F Floor Sampling

Real-time readings, identical to those taken on the waste pile cap, were taken from the restored Basin F floor, which had been covered with a clay and topsoil cap. The Basin F floor readings were taken at 115 regularly spaced locations marked by sandbags, as depicted in Figure 3.3-3. The weather conditions and the physical appearance of the cap during each sampling episode were recorded prior to commencement of sampling. Monitoring was conducted on a schedule identical to that of the waste pile cap, although actual monitoring days differed for the two efforts.

In addition to the real-time monitoring, three flux chamber sampling episodes were conducted at specific locations on the waste pile cap and within the boundaries of the restored basin (see



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Figure 3.3-3

Locations of Sandbag Markers for Real-Time
 Basin F Floor Monitoring

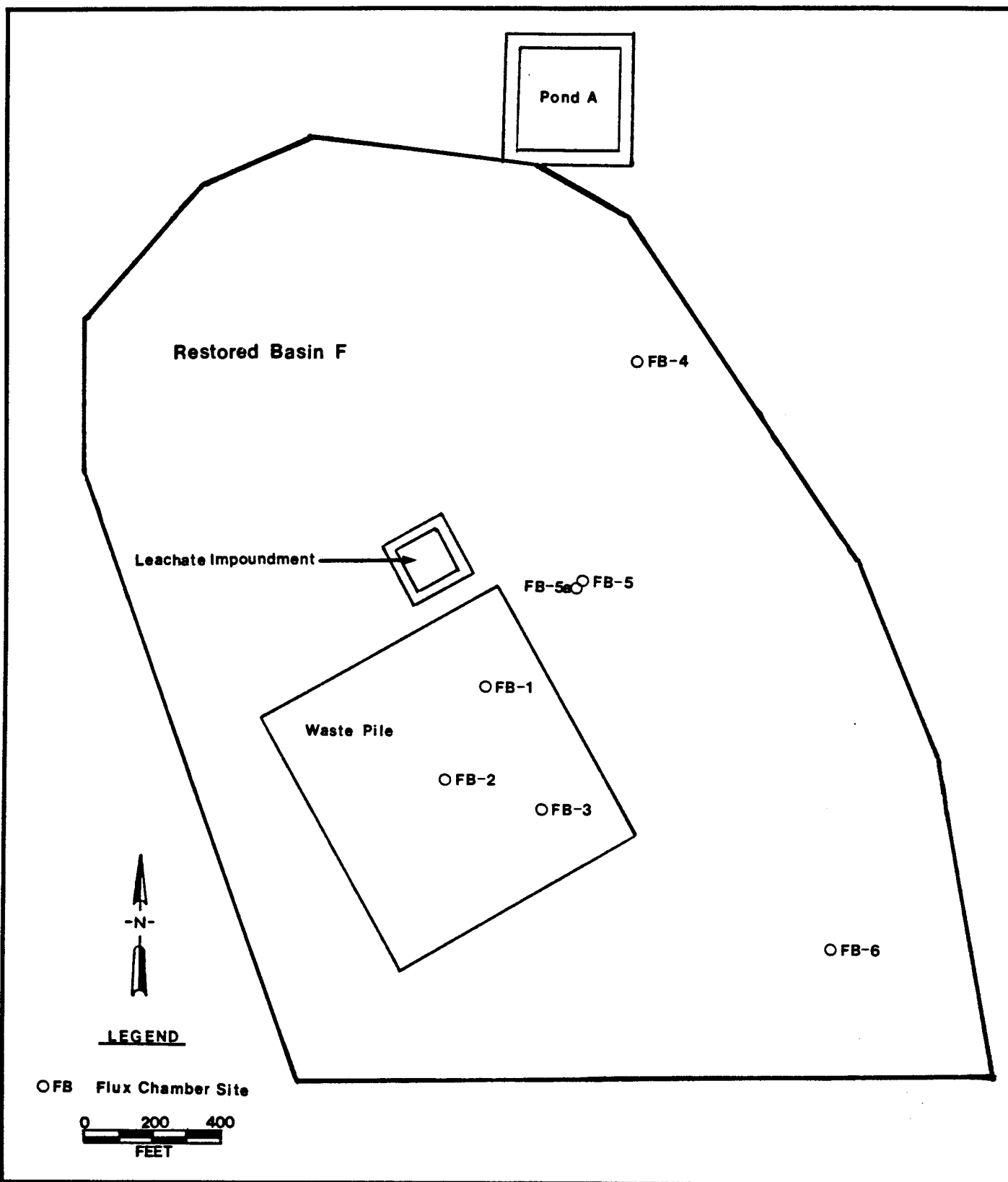
Figure 3.3-4). Sites FB-1, FB-2 and FB-3 were located on the waste pile. Sites FB-4, FB-5, FB-5a and FB-6 were located along the eastern side of the former Basin F floor.

These samples were collected and analyzed by AeroVironment, Inc. (AeroVironment) of Monrovia, California, and the results are discussed in Section 4.8.2. The flux chamber sample locations were prepared a few days in advance by removing all vegetation in excess of three inches high. The sample pad was then covered to protect it from precipitation for several days, to ensure dry soil surface conditions. At the time flux chamber sampling was being conducted, IRA-F personnel monitored HNu and OVA readings at ground level and at the nearest vent opening. Soil temperatures were also measured in soils adjacent to the sample pad. The bottom edges of the stainless steel flux chambers were set into the soil to a depth of one inch, then pressurized with ultra zero grade air. Once the soil seal was verified, Summa passivated canisters were used to collect samples to be analyzed for VOCs. The SVOCs samples were collected on PUF media. Both types of samples were collected on air drawn from within the flux chamber enclosure.

3.3.3 Pond A Vent Sampling

Pond A is a double-lined liquid storage pond located just north of Basin F. The pond is covered with a high density polyethylene cover, and has four special vents, one in the middle of each side of the pond. The vents are equipped with trip valves that open to allow emission of gases and close to prevent entrainment of air beneath the pond cover. As a result, the pond gases are emitted in short pulses. Sampling the pond vents required a sample duration that spanned several pulses of the trip valve. All four Pond A vents were sampled with the real-time monitors during each of the monthly and quarterly episodes. Vent locations are illustrated on Figure 3.3-5.

On three separate days in 1990 the Pond A vents were sampled using the canister sampling method described for the waste pile vents. For each of the three sampling episodes, the one pond vent with the highest real-time readings of total organics was sampled. Samples were drawn from within the throat of the vent over a duration which included at least three pulses of the trip



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Figure 3.3-4
Flux Box Sampling Locations

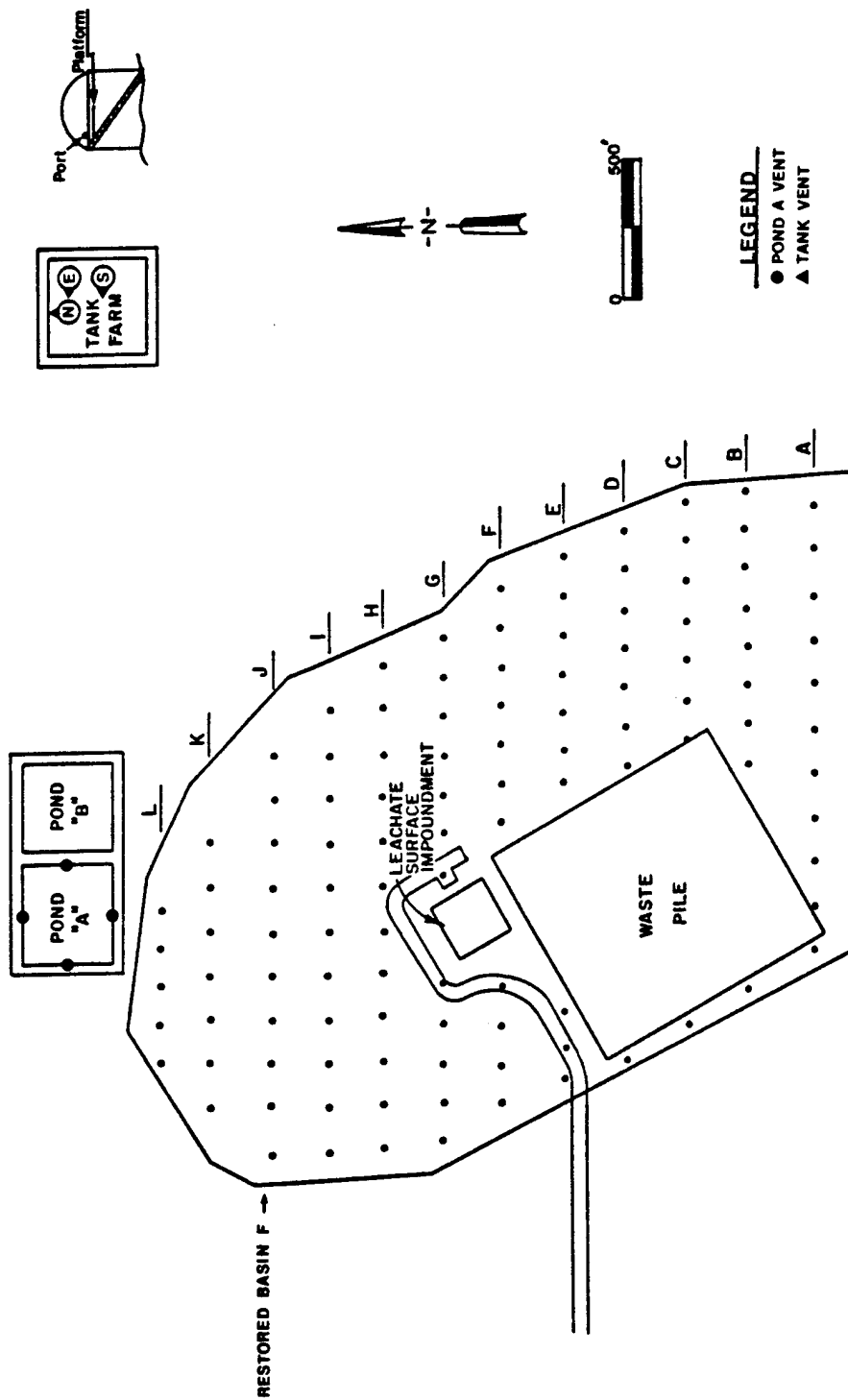


Figure 3.3-5

Locations of Tank Farm, Ponds A&B, Waste Pile and Restored Basin F

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valve. These canisters were sent to a laboratory for analysis of the target compounds and for analytical scans of nontarget compounds.

3.3.4 Tank Sampling

The three liquid storage tanks located near Basin F are covered by metal roofs with passive vents atop each tank. The sampling crew did not have access to the roof, but was able to perform real-time sampling of tank vapors through a Tygon tubing extension for the analyzer probes. Real-time tank vapors readings were taken with the OVA and HNu on the same monthly and quarterly schedule as the waste pile cap and Basin F floor monitoring. While sampling with canisters, the sampling crew accessed the tank vapors through a sample port at the top of the tank access stairway. Canister samples were drawn from the tanks three times during 1990, using sampling methods similar to those described for the waste pile vents in Section 3.3.1. These samples were drawn from within the vapor space above the tank liquids on the same days as Pond A vent sampling. Similar target and nontarget analyses were performed on these canisters as for Pond A vent samples and waste pile vent samples. Figure 3.3-5 illustrates the locations of the tank farm and the sample ports on the tanks.

3.4 METEOROLOGICAL MONITORING PROGRAM

Although the meteorological data collection was conducted by the CMP, a description of the program is included here because the IRA-F sampling program depended on the data for volume calculations. Some of the special sampling depended upon changes in the atmospheric pressure, so meteorological data was essential. Other aspects of data interpretation for the IRA-F program also required use of meteorological data.

3.4.1 Program Objectives

On-site meteorological data were used by IRA-F to provide interpretation of the air quality data. The data were used primarily to identify atmospheric conditions associated with normal, and high (high event), target analyte levels collected during IRA-F sampling. Prevailing wind flow, wind speed, peak wind gusts, temperature and precipitation all influence the release and dispersion of

atmospheric emissions. The meteorological database has been used to interpret average conditions as well as to examine seasonal and diurnal effects. For example, gusty winds will cause higher levels of TSP, PM-10, metals and perhaps SVOCs. This type of information is essential to interpreting air sampling results. Emission of VOCs can be greatly influenced by temperature, moisture and wind speed. Fundamentally, the meteorological data can be used to characterize potential sources, to assess variability in air quality data, to describe incursions from potential off-site sources, and to provide a sound understanding of on-site air quality conditions.

Another objective of the meteorological assessment is to determine the representativeness of the collected air quality data with respect to associated meteorological conditions. Meteorological factors change not only from season to season, but also from year to year. The variability of meteorological conditions during sampling influences air sampling results. Factors which influence pollutant levels in ambient air at specific locations include such variables as anomalous precipitation or drought conditions, extensive snow cover, active snowfall, strong winds, prevailing wind direction, very warm temperatures or poor dispersion conditions. Data on such actual local conditions are essential for correct interpretation of sampling results. Consequently, the RMA meteorological data has been extremely useful in interpreting and assessing air quality conditions over the entire IRA-F period, as well as aiding in projection of long-term trends for the future. Although the meteorology program is not a part of the IRA-F program, it has been of great importance to the IRA-F program, and relevant details are provided below.

3.4.2 Meteorology Program Overview

Meteorological parameters have been monitored at a total of seven locations within the RMA boundaries from 1981 through the end of the IRA-F program. The various meteorological monitoring sites were selected to allow data acquisition at points as close as possible to potential major sources of contaminants on RMA. The locations, discussed below, are shown in Figure 2.2-2. Three 10-meter towers (M1, M2, and M3) were installed in 1981 and were maintained by RMA until they came under the responsibilities of the CMP. A temporary 10-meter tower, BF Site, was installed and operated by EBASCO from April 1988 through April 1989. From

October 1988 through May 1989, a pair of 2-meter towers, RIFS1 and RIFS2 were employed and maintained by EBASCO. In May of 1989 a fourth permanent 10-meter tower (M4) was added to the system. The CMP maintained responsibility for operating the meteorological system during the IRA-F monitoring period. This distribution of responsibility continued through the end of the IRA-F program. An upgrade to the four tower system (M1, M2, M3 and M4), which encompassed the addition of remote access by radio-telemetry and phone modem, was activated on February 1, 1989. From May 1989 through the end of the IRA-F program, only the four tower system of M1, M2, M3 and M4 was active.

3.4.3 Monitoring Equipment and Strategy

The meteorological monitoring system consisted of meteorological towers located at strategic points within RMA. Sensors at various sites were installed at 10 meters, two meters or one meter, depending on the tower and the parameter. On the 10-meter towers, wind speed, wind direction and temperature were recorded by sensors fixed at the 10-meter level. Temperature sensors installed on M1 at 10 meters and 2 meters were used to calculate temperature difference (10m - 2m). In addition, meteorological sites collected and recorded precipitation at a height of one meter above the ground. Relative humidity was measured at M1. Solar radiation was recorded at M2 and M3 from sensors positioned at a height of one meter above ground level. The pressure sensor, located at M4, recorded atmospheric pressure at a height of approximately 1.5 meters above ground level, and portable barometers were used for some field work. Maximum gust wind speeds were recorded by M1, M2 and M3. For all towers, sigma theta (a function of wind stability) was calculated based on the wind direction registered by each sensor. While the 2-meter towers were in use, they recorded wind speed, wind direction and temperature at a height of two meters above ground level.

3.4.4 Meteorological Data Acquisition

Each meteorological tower was equipped with a datalogger that could electronically store several weeks of data at a time. These data were routinely retrieved into the database by the remote telemetry system which was activated in February 1989. Prior to the addition of the remote

retrieval system, data were downloaded to a laptop computer, then entered into the database. These data were verified by scanning the data and/or by routine data validation against reduced strip charts.

3.4.5 Data Applications

Meteorological data were used in several ways during the IRA-F program. Real-time pressure trends and wind speed were used to determine the suitability of ambient conditions for special sampling such as vent and tank readings. Temperature and barometric pressure were employed to compute standardized flow volumes for sampler calibrations and for collected air quality samples. All parameters, including wind, atmospheric stability, temperature and pressure were collected and correlated with long-term regional data to determine the representativeness of a sample period. These data were also evaluated to help interpret and examine sampling results from anomalous or otherwise interesting days from year to year. The various meteorological parameters were employed to compare the actual data with the potential source impacts, as predicted by atmospheric dispersion models.

3.4.6 Meteorological Databases

A single composite database representative of overall RMA conditions was developed based on data collected during the period when meteorological sites were operating on RMA. The "BF" Site data were the primary meteorological data source for the composite database for the period of April 1988 through January 1989. Starting in February 1989 and continuing through early May 1989, the M1 site was the primary data source for the composite database. By early May 1989, the new monitoring location (M4), was operational, and from that time through the end of the IRA-F sampling the M4 data were the primary source for the composite. Data from the other three active sites were used to complete certain parameters not monitored at M4, or to substitute for invalid or missing data. For most parameters the amount of data requiring substitution was small (3 percent or less). When no valid RMA data were available, National Weather Service data gathered at Stapleton were used.

The data which was used during the IRA-F program was the composite database for RMA that came from three of the RMA towers. The M4 site supplied wind speed, wind direction, temperature, barometric pressure and precipitation. Relative humidity, temperature difference (10m - 2m) and peak wind gust were provided by the M1 site, while solar radiation data from M2 was used. Before the winter of 1990, the winter precipitation data were obtained from Stapleton. The RMA winter precipitation data were not considered accurate at that time. Complete listings and discussion of this composite database may be found in the Air Quality Data Assessment Report for the CMP (Stollar, 1989; 1990; 1991).

3.4.7 Meteorological Data Recovery

The recovery rates for each parameter from FY89 and FY90 meteorological data are summarized in Table 3.4-1. Recovery percentages were based on data recovery versus the total number of possible hours for data acquisition during the period. Hourly values for each parameter were considered valid only if a minimum of 45 minutes data could be verified as accurate. Data from calibration periods and equipment failures were treated as invalid.

3.4.8 Dispersion Model Applications

The meteorological conditions were used in a dispersion model to assess impacts from a hypothetical Basin F source.

Both the short-term (ISCST) and long-term (ISCLT) versions of the EPA Industrial Source Complex (ISC) Models (EPA, 1986) were used in the analysis. This is an EPA-approved general purpose model used to predict air quality impacts for a wide range of sources including surface area sources. The modeling results in this case did not indicate actual ambient concentrations, but rather, indicated relative strength or potential concentration levels based on a given set of meteorological conditions and on a hypothetical emission source strength from a Basin F area source. The RMA composite meteorological data was applied to the ISC dispersion model. Results of the model were used to generate dispersion curves for each of 16 directions around Basin F. Both the worst case 24-hour and the annual average curves were generated. The worst

Table 3.4-1 Summary of RMA Meteorological Monitoring for FY89 and FY90

Parameter	FY89 % Recovery	FY90 % Recovery
Wind Speed	99.8	99.7
Wind Direction	99.8	99.7
Sigma Theta	99.8	99.7
Temperature	99.8	100.0
Relative Humidity	99.4	89.2
Barometric Pressure	89.8	94.7
Solar Radiation	89.2	100.0
Precipitation	100.0	100.0
Maximum Gust	97.5	99.6
Temperature Difference (10m-2m)	NA*	98.6
Stability	<u>99.8</u>	<u>99.7</u>
Program Total:	97.5	98.3

* NA = Data not available, instrumentation not yet installed

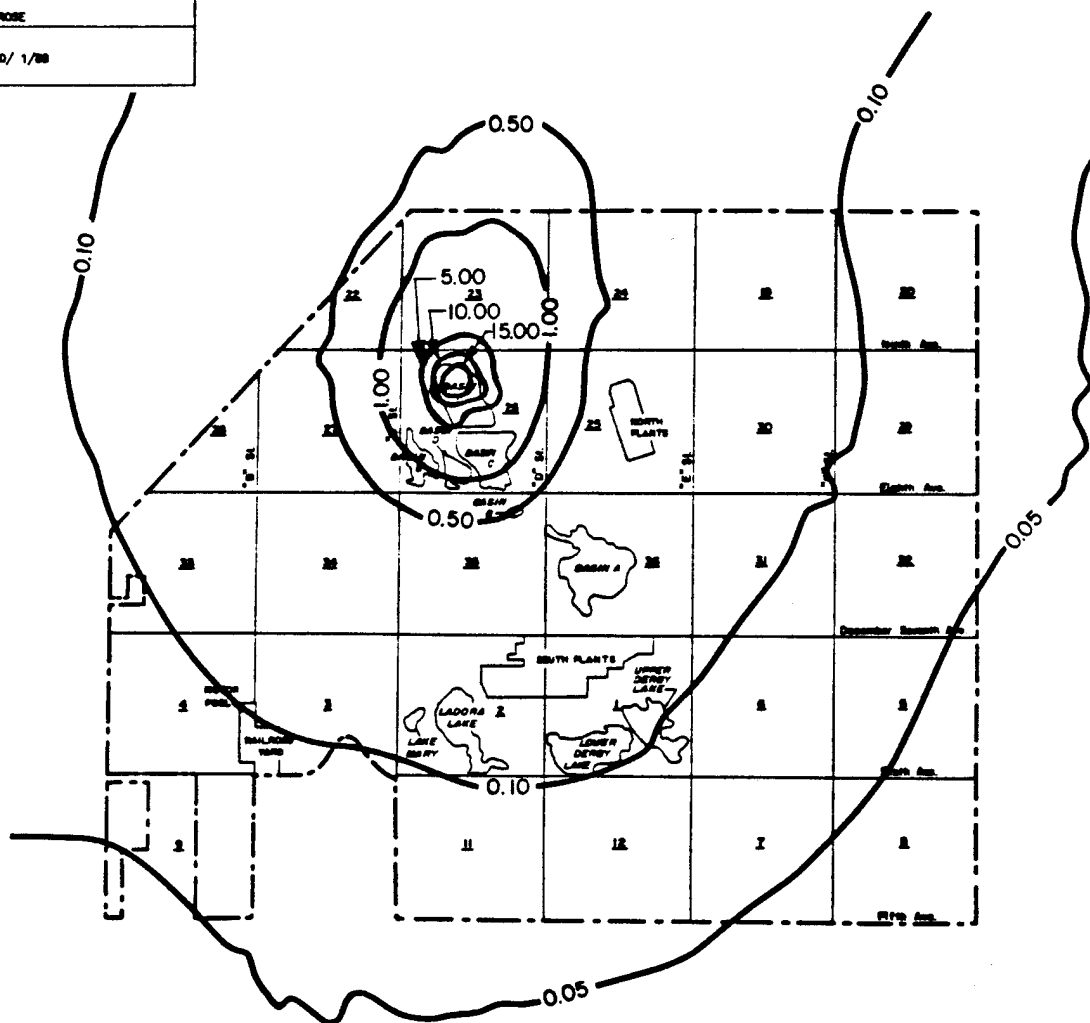
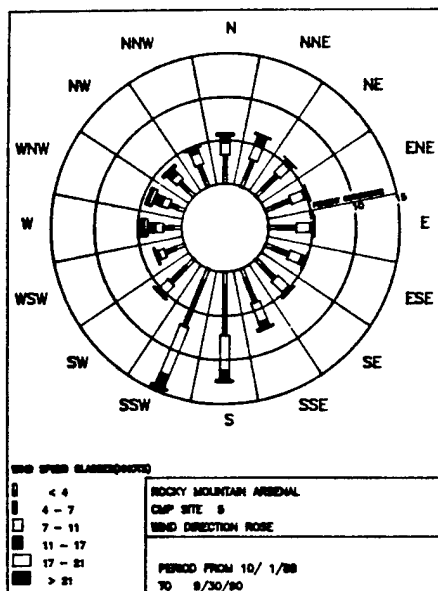
case 24-hour ISCST models were generated using the noon-to-noon meteorological data for the corresponding IRA-F sampling periods. Annual averages was performed on a combined data set from Phase 3 and Phase 4. The results of this modeling run are presented in Figure 3.4-1. Acceptable Ambient Concentrations (AACs) were developed for the list of target analytes. The concurrent air quality data and the meteorological patterns were combined to calculate estimates of atmospheric concentrations for both receptors, for comparison to the AACs.

3.5 DATA PROCESSING PROCEDURES

A key component to the integrity of the collected data is the series of steps used to calculate atmospheric concentrations. Each of the data gathering and computational steps is described in this section. These steps ensured that the results of the monitoring effort were accurate and were validated in accordance with good technical procedures. Based on the current meteorological conditions and the standardized flow rate obtained from the latest sampler calibration, the total volume of air sampled was calculated for each sample. The laboratory reported the analyte mass for each sample. These data were used to calculate the ambient concentrations.

3.5.1 Sample Volumes

Sample volumes are one key component for calculating the ambient concentrations. The volumes were calculated by entering field data into a preset computerized spreadsheet. The data used to generate the sample volumes varied with the type of sampler and the flow indicator. Meteorological data were also used in the conversion of flow rates and actual volumes into standard volumes. The calculated volumes were adjusted based on the quarterly calibrations of each of the samplers. The computational procedure for each sampler type is summarized below. Detailed computational procedures for sampler calibration and flow volume calculations are presented in the "IRA-F Air Monitoring Program" standard operating procedures (SOP) manual in Appendix A.



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Figure 3.4-1

**Average Wind Rose and Mean Dispersion Pattern
 for a Hypothetical Basin F Source, Based on FY89
 and FY90 Composite Meteorological Data**

3.5.1.1 Sample Volumes for Total Suspended Particulates, PM-10, and Metals

A mass flow controller was installed in each sampler to provide a constant, standardized flow rate throughout a given sample period. The flow rate was set (as-left flow) during each quarterly calibration and checked (as-found flow) just prior to the succeeding calibration. The average flow for a specific sampler during a given calendar quarter was assumed constant and computed as the average of the as-left and the as-found flows. (The as-found flow was measured at the end of one quarterly sampling period, and the as-left flow was measured during calibration for the upcoming quarter.) When a sampler's flow recorder indicated more than a 10 percent variation at any point during a given sample period, an adjustment to the sampler flow rate was made using the regression constants from the previous calibration. The average rate of flow was multiplied by the elapsed sample time to determine total sample volume for each sample.

3.5.1.2 Sample Volumes for Semivolatile Organic Compounds and Organochlorine Pesticides

A time-weighted average flow rate was generated from the four MagnehelicTM flow check values using the calibration-generated linear relationship between the square root of the magnehelic reading and the actual flow rate. A correction factor for standard conditions was obtained for each sample period from the on-site meteorological data and applied to the actual flow rate to obtain the standardized flow rate. The standard flow rate was multiplied by the elapsed time to provide the standard volume for the sample.

3.5.1.3 Sample Volumes for Volatile Organic Compounds and Mercury

The four rotameter flow check values were entered into a regression equation obtained from the most recent calibration to determine the actual flow. The standard volume correction factor, based on the on-site meteorological conditions was applied, and the sample volume was determined by multiplying the average standardized flow rate by the elapsed time for the sample.

3.5.2 Laboratory Results Data Reporting

The subcontractor laboratory, Midwest Research Institute (MRI) of Kansas City, Missouri, was used to conduct the sample analytical work for the IRA-F program. The laboratory procedures are described in Section 3.6. For data processing purposes, the laboratory provided a determination of the mass of each of the selected target analytes from each sample. For each analyte, the laboratory had established a certified reporting range, with both an upper and lower certified reporting limit (CRL), based on reported mass. The quantity of sample mass was reported if it was above the certified reporting limit (CRL), and was reported as "below the CRL" if it was below the LCRL. All samples except VOCs could be diluted to provide data within the certified range (when the initial sample results were above the upper CRL). For VOCs, "estimates" were reported for data values above the upper certified reporting limit (UCRL). These estimates have been used in this report.

The PMRMA did not require that TSP and PM-10 gravimetric analyses be certified. However, the established LCRL was 2 μg , which was equivalent to an atmospheric detection limit of 0.001 $\mu\text{g}/\text{m}^3$. These analyses were quantitative (gravimetric) mass measurements only.

The laboratory reported its results into the IRDMS, which had been set up at RMA for handling environmental data. The IRDMS procedures were very complex, requiring submittal of analytical results in a specified hard-copy and digital electronic format. The data processing procedures included running a "group check" to verify that all data within each lot of samples met established criteria. Group check procedures included verifying the site identifiers to ensure validity, a check of the range of lot control samples, a check for the compatibility of QC sample identifiers and the format for each lot to see that all required data were entered. A separate "record check" was performed to ensure that the reported results were within the certified range, that values outside the certified range were properly flagged, that confirmation analyses had been provided where necessary, and that the individual record data were complete.

3.5.3 Computation of Concentrations

After the laboratory submittal passed the verification procedures, the sample mass and sample volume data were combined to calculate a sample concentration. The raw data that had been used to calculate concentrations were spot checked to verify accuracy of the computations. After the concentrations had been determined, there was a technical review of the data by an air quality specialist. This review consisted of checking the concurrent readings of target analytes for all stations sampled on one day, and a comparison to long-term data, including trends, for critical target analytes to determine if the data were comparable and reasonable. Sample concentrations which failed to meet these criteria were either discarded as erroneous or were entered into the database and flagged as estimated or questionable values.

For all analytes except the VOCs the computation of sample concentrations was made from a rather straightforward use of the raw sample mass and volume data. For VOCs, however, the sample mass was collected in two separate tubes (Tenax and Tenax-and-charcoal) connected in series. Sample mass was computed by addition of these two masses, which were subject to some special conditions relating to the nature of the data. If the target analyte was not detected above the LCRL in either tube, the total sample was reported as below the LCRL. If the reported values for both tubes were within the certified range, the sample weights were added together, and the calculation of the concentration was based on the sum of the mass weights. If one sample weight was above the LCRL and the other was below the LCRL, the reported value above the CRL was used, and the other tube sample weight was assumed to be "zero." If either tube had a value above the certified range, the value was reported as an estimate, and the sum of the two weights was used.

For selected samples, the laboratory performed a "scan" of all peaks for the GC/MS chromatogram. All peaks above 10 percent of the internal standard were examined. To the extent possible, these peaks were identified from the National Bureau of Standards' library of organic compounds, which can be found in Laboratory Data Validation Functional Guidelines for Evaluating Organic Analysis and in the Statement of Work for Contract Laboratories Program

(CLP), February 1988. The sample weights for each of these compounds was reported. In a similar fashion, the concentrations were computed using the sample standard volume.

3.5.4 Computation of Average Concentrations

For most of the target analytes, a substantial number of sample concentrations were reported as below the LCRL. It was not a sound practice to assume that all these values were zero; therefore a special computational scheme was used to develop the average concentrations above the LCRL for this program. If a target analyte had one or more reported values above the LCRL for a specific sample, those values were used in computing the average, and all samples below the LCRL were assumed to be one-half the LCRL. This procedure had been used on other programs at RMA. If there were no detections above the LCRL, the average was reported as "below the CRL". These averages were computed separately for each site. Therefore a single analyte could have had some detections along with an average concentration at one site, and have an average below the LCRL at another site. This averaging technique provides a conservative estimate of average concentrations.

3.6 LABORATORY ANALYSIS PROGRAM

The objective of the laboratory analysis program was to provide PMRMA with reliable, statistically supportable and legally defensible air quality data for airborne contaminants at RMA. Laboratory analysis procedures were reviewed and certified by PMRMA.

Analytes for the program were selected from an evaluation of contaminant sources at RMA, the compounds associated with previous activities at the activity sites at RMA, and compounds detected in previous air, soil and water monitoring investigations. A list of target analytes sampled under the IRA-F program may be found in Table 3.1-1. Table 3.6-1 summarizes the analyses along with the type of certification procedure, the reference method and the type of analytical method used.

Table 3.6-1 Analytical Methods for IRA-F Air Quality Monitoring Program

Parameter	PMRMA Certification	Reference Method	Certification Method	Method Number
TSP	None	40 CFR Part 50, Appendix B	Gravimetric	N/A
PM-10	None	40 CFR Part 50, Appendix B	Gravimetric	N/A
Asbestos	None	NIOSH 7400	Phase Contrast Microscopy	N/A
VOC	Semi- quantative	EPA T0-1 with EPA Method 624	GC/MS	E-7
SVOC	Semi- quantative	EPA Method T0-4	GC/MS	F-7
OCP	Quantative	Modified EPA Method 608	GC/ECD	H-7
Metals	Quantative	NIOSH 7300	ICAP	G-7
Lead	Quantative	40 CFR Part 50, Appendix G	ICAP	G-7
Arsenic	Quantative	EPA Method 206.2, 1979	Graphite Furnace/AA	G-7
Mercury	Quantative	AIHA, 1976	Cold Vapor/AA	J-7

GC/MS = Gas chromatography/mass spectrometry
 GC/ECD = Gas chromatography/electron capture detection
 ICAP = Inductively coupled argon plasma
 AA = Atomic absorption
 CFR = Code of Federal Regulations

The defensibility and technical quality of data generated in this program were assured by documenting all the analytical procedures and by requiring all data to exceed minimum analytical method requirements with respect to instrumentation calibration. Sample preparation, materials shipping, handling and chain-of-custody procedures followed the protocol outlined in the IRA-F SOP (Appendix A).

The Chemical Analytical Program for IRA-F performed certified RMA methodologies as required in the RMA Chemical Quality Assurance Plan (CQAP) version 1.0, July 1989. The nonchemical analyses for particulates (TSP and PM-10), used EPA-approved methods. Certification by PMRMA was not required for nonchemical analyses.

Analytical techniques used during the certification process were based on good laboratory practices, the historical activities at RMA, and applicable regulatory requirements. Certification procedures required the laboratory to obtain the target analyte list and specified protocols from the Army before proceeding with analytical methods development. The complete certification process and QA protocols are found in the CQAP, but have been condensed below, along with the methods, for a synopsis of PMRMA's analytical process.

3.6.1 PMRMA Certification Program

Before using an analytical method to determine the constituents of an environmental sample, a laboratory was required by the PMRMA to demonstrate the ability to perform the methods for a specified list of target analytes. Individual analysts and instrumentation were not specifically certified along with the method, but the laboratory had to ensure that trained, qualified staff were employed to perform the analyses. All chemical analyses were conducted in "lots," or groups of samples which were analyzed together. The use of these lots allowed an effective means of demonstrating analytical control for that group of samples.

Final methodologies employed for the IRA-F program were based on PMRMA certification procedures. These procedures ensured the accuracy and integrity of the collected database

through a control chart process described below. The certification was extremely rigorous and consisted of pre-certification and certification of the analytical methodologies.

Pre-certification entailed analyzing, in a single day, a series of concentrations containing all target compounds. Responses were compared to actual concentrations, plotted on a calibration curve, and assessed for linearity. Analysis of the curves was performed in duplicate, and tested for lack of fit (LOF) and zero intercept (as shown in Appendix E of the CQAP), to demonstrate linearity between instrument response and standard concentration. The method certification process entailed analysis of spiked standard samples and was used as the demonstration of the laboratory's ability to perform the analysis.

Standard sampling media varied depending on the type of analysis. Standard collection media materials for the IRA-F program included PUF plugs for OCPs and SVOCs, Tenax and Tenax-and-charcoal tubes for VOCs, Hydrar-filled tubes for mercury and glass fiber filters (Whatman EPM2000) for metals and arsenic. For each method, a tested concentration range was determined based on the target reporting limit, which was specified by PMRMA or by the technologically lowest obtainable detection limit of the method and the limits set by the presiding regulatory agency for environmental quality.

3.6.1.1 Certified Reporting Limits

Data from the certification of analytical methods were used to determine the method's CRLs, accuracy adjustments for the sample data and control chart limits. Table 3.6-2 summarizes the CRLs for analytes sampled under the IRA-F program. Samples with values outside this range were less than (LT) or greater than (GT) the certified range of values. Dilutions were performed whenever warranted to bring the GT values within the certified range.

When dilutions could not be performed, as in the case of VOC analyses, GT values were estimated to provide the approximate magnitude of the target analyte concentration. These values were considered estimates based on the nonlinear portion of an instrument's capabilities and were

Table 3.6-2 Certified Reporting Limits for IRA-F Air Monitoring Program

Parameter	Certified Reporting Limit (Lower Certified Range)	Atmospheric Detection Limit
TSP	2 μg	0.001 $\mu\text{g}/\text{m}^3$
PM-10	2 μg	0.001 $\mu\text{g}/\text{m}^3$
Asbestos	7 particles/ mm^2	0.002 part/ml
VOC	0.005 to 0.040 μg	0.017 to 0.139 $\mu\text{g}/\text{m}^3$
SVOC	4.000 to 52.00 μg	0.014 to 0.181 $\mu\text{g}/\text{m}^3$
OCP	0.100 μg	0.0004 $\mu\text{g}/\text{m}^3$
Metals		
Cadmium	0.648 μg	0.0004 $\mu\text{g}/\text{m}^3$
Chromium	8.360 μg	0.005 $\mu\text{g}/\text{m}^3$
Copper	14.20 μg	0.009 $\mu\text{g}/\text{m}^3$
Lead	8.190 μg	0.005 $\mu\text{g}/\text{m}^3$
Zinc	5.650 μg	0.003 $\mu\text{g}/\text{m}^3$
Arsenic	0.625 μg	0.0004 $\mu\text{g}/\text{m}^3$
Mercury	0.089 μg	0.809 $\mu\text{g}/\text{m}^3$

not technically certified. Therefore, they do not appear in the IRDMS, but are available in the analytical data package stored in RMA records.

3.6.1.2 Accuracy

Sample results were adjusted for analytical accuracy. Accuracy is defined as the difference between the individual analytical measurements and the true value, corresponding to the sum of systematic and random errors. Accuracy was determined by the slope of the analytical response curve for the complete data set. The accuracy estimate for the complete certification data set was incorporated into the Installation Restoration Data Management System (IRDMS). An adjustment for accuracy was made after a thorough QA review was performed before final acceptance of the data. Accuracy assessment was applied to all field data samples.

3.6.1.3 Control Charts

For each analytical lot of samples, the laboratory conducted test recoveries of specified surrogate compounds. The surrogate recoveries, or QC data, were used to assess the validity of the lot analyses. Once the QC data were obtained by the laboratory, a series of control charts were used to monitor the fluctuations in the accuracy and precision of an analysis and to detect trends in these variations from lot to lot. Control charts for each method were initiated for the first certified analysis, and consisted of tabulated data and a graphical portrayal of the accepted recovery ranges. The initial certification data established the mean and the range measurements which would be acceptable. Ranges were based on a 95 percent confidence limit or a factor of 1.96 times the standard deviation from the mean of the average recoveries. Data used in control charts were not adjusted for accuracy since the QC data was compared to control chart limits from certification to demonstrate that analyses within a lot were under control. Accepted data points were then used to update control charts and to provide a continuously updated graph of the method performance. If recovery results were within the control limits, then analyses of the samples in a lot were considered in control and analysis proceeded. If recovery results fell outside the control limits, investigation of the problem was required, and corrective action was taken as necessary, prior to continued sample analysis.

Control charts were reviewed at four levels before the analytical lot could be accepted. The analyst checked the recovery results against control chart limits, before analyzing the samples. The laboratory quality assurance coordinator (LQAC) looked for trends and outliers compared to the control chart limits. It was at this point that all information pertaining to the analysis was compiled and a case narrative of relevant events was completed. This narrative and the control charts were sent to the project QA coordinator (PQAC). The PQAC assessed acceptability of the lot based on the LQAC's analysis and control chart trends. A formal QA review was performed and recommendations were made to accept or reject the lot of analyses. The entire package was then sent to the PMRMA for final review. The chief of the Laboratory Support Division (LSD) transmitted the results and conclusions of the review back to the PQAC, to be distributed among the participating laboratories. Accepted data were placed in the official IRDMS database. Rejected data were not lost, but were placed in a "rejected" file, along with the reasons they were not accepted. Data utilized in reports were taken from the official database except where otherwise specified.

3.6.2 Methods

Analytical methods for all parameters except particulates were PMRMA certified with methods based on EPA or NIOSH requirements. These methods are described in detail in the following sections.

3.6.2.1 Organochlorine Pesticides

The method used was PMRMA Method H-7, Analysis of OCP in Environmental Air Samples by GC/ECD, performed by MRI. The general method employed extraction of contaminants, with methylene chloride, from an ambient air sampling cartridge containing a PUF and a quartz fiber filter. The extract was divided for use with PMRMA Method F-7 for SVOCs and condensed, solvent exchanged to hexane, and cleaned with alumina. An aliquot of extract was analyzed by GC/ECD using a DB-17TM megabore chromatography column manufactured by J & W Scientific. Qualitative identification was based on retention time of the compound. Quantitation was performed using an external standard curve. Sample results were reported as micrograms per

cartridge sample (µg/sample). Confirmation of positive results was performed using a GC/ECD with a DB-5TM (J & W Scientific) capillary column.

Certified concentrations ranged from 0.100 µg to 2.02 µg per PUF sample, depending on the target analyte. The allowable holding time until extraction was seven days and laboratory analysis occurred within 40 days of extraction.

3.6.2.2 Semivolatile Organic Compounds

The analytical method used for SVOCs was PMRMA Method F-7, Analysis of SVOCs in Environmental Air Samples by GC/MS, performed by MRI. The general method employed extraction of contaminants, with methylene chloride, from an ambient air sampling cartridge containing a PUF plug and a quartz fiber filter. The extract was condensed (one-half the extract from method H-7, above) and an aliquot analyzed by GC/MS configured with a DB-5TM fused silica capillary column (J & W Scientific). Quantitation was performed using an internal standard. Sample results were reported as µg per cartridge within the certified range between 5 µg and 100 µg, depending on the compound of interest. The allowable holding time for this type sample was seven days for extraction and 40 days for analysis.

Method CM02 was a recertified F-7 method, and was employed by MRI from May 1990 to September 1990 for SVOC samples that were collected from April 11, 1990 to the end of the IRA-F program. This method was similar to Method F-7, with only the lower certified reporting limit changed. Parathion was dropped as a target analyte because its analytical response was not proportional to input concentrations.

3.6.2.3 Metals and Arsenic

The analytical method employed for metals and arsenic was PMRMA Method G-7, Analysis of Metals and Arsenic in Ambient Air by ICAP Atomic Emission Spectrometry (AES) and Graphite Furnace Atomic Absorption (GFAA) Spectroscopy, performed by MRI. The general method required digestion of a portion of the TSP filter with concentrated nitric acid and 30 percent

hydrogen peroxide. The digestate was analyzed by ICAP/AES for metals and by GFAA for arsenic. Calculations were performed using an external standard. Certified concentrations ranged from 0.625 µg to 500 µg per filter depending on the target analyte. The allowable holding time for these samples was six months.

3.6.2.4 Mercury

Mercury was analyzed using PMRMA Method J-7, Analysis of Mercury in Ambient Air by cold vapor atomic absorption spectrometry (CVAAS), performed by MRI. The general method required digestion of Hydrar-filled glass traps with concentrated nitric and hydrochloric acids. The digestate was further processed with stannous chloride and analyzed by a CVAAS. Calculations were performed using external calibration. Certified concentrations ranged from 0.0889 µg to 1.0 µg per trap. The allowable holding time prior to analysis for these samples was 28 days.

3.6.2.5 Volatile Organic Compounds

The analytical method used for VOCs was PMRMA Method E-7, analysis of VOCs in Environmental Air Samples by GC/MS, and was performed by MRI. The general method consisted of spiking the Tenax and Tenax-and-charcoal traps with an internal standard. Each trap was then heated and desorbed into a GC/MS. The VOCs were separated by a temperature-programmed GC and detected by an electron multiplier. Concentrations of VOCs were calculated by the internal standard method. Certified concentrations ranged from 5 nanograms (ng) to 100 ng depending on the target analyte. The allowable holding time for samples collected with this media was 14 days.

Descriptions of these PMRMA certified analytical methods are on file at the LSD at RMA. The original method certification data and software copies generated by MRI are also in LSD files.

3.6.3 Nontarget Compounds

When chromatographic peaks appeared in the GC/MS VOC and SVOC analyses which were not target analytes, surrogates or internal standards, they were labeled as potential tentatively identified compounds (TICs). These TICs were qualitatively identified by a GC/MS library search and the identifications assessed by the analyst and data reviewer.

3.6.3.1 Unknown Compounds

For each sample requiring TIC identification, the laboratory conducted a mass spectral search on all chromatographic peaks which had an area/height ratio greater than 10 percent of the size of the nearest internal standard. Any TICs were reported as unknowns in the IRDMS database and were assigned a "UNK" prefix plus the relative retention time (RRT) of the chromatographic peak which was a three digit number. The RRT equals the retention time of the unknown peak, divided by the retention time (RT) of the nearest internal standard, times 100. To distinguish SVOC from VOC unknowns, 500 was arbitrarily added to the RRT of the SVOC unknown. Examples of both equations are given below:

Volatile Unknown

$$\text{Reported RRT} = \frac{\text{RT of Unknown}}{\text{RT of Internal Standard}} \times 100$$

Semivolatile Unknown

$$\text{Reported RRT} = \frac{\text{RT of Unknown}}{\text{RT of Internal Standard}} \times 100 + 500$$

These values were reported to the PMRMA IRDMS database as "UNKXXX" where XXX was the reported RRT calculated in the above equation.

3.6.3.2 Identification of Unknowns

The PMRMA IRDMS database software does not allow for any "possible" identification of unknowns. Therefore, to assess the importance of an unknown, a tentative identification was given to the data users. The guidelines followed by the laboratory in providing this information are outlined below:

- a. Major ions from a reference spectrum should be present in the sample spectrum.
- b. The relative intensities of the major ions should agree within ± 20 percent between the sample and reference spectra.
- c. Molecular ions present in the reference spectrum should be present in the sample.
- d. Possible background contamination, interferences or correlation of additional unknowns or target analytes must be addressed.
- e. When the above criteria are not met, but in the technical judgement of the data reviewer or mass spectral interpretation specialist, the identification is correct, the identification may be reported.
- f. If, in the data reviewer's judgement, the identification is uncertain or there are extenuating factors affecting the compound identification, the TIC result may be reported as unknown.
- g. If at all possible, identification of a compound group or type of chemical such as hydrocarbon or oxygenated compound shall be made, if the data reviewer can extract the information.

Once a TIC was identified and given an UNK number, an estimation of its concentration was calculated. TIC values were determined by the same calculations described for certified compounds except the Response Factor (the ratio of a chemical compound and a known internal standard, in terms of instrument response) was equal to 1.00 and the Area of the parameter measured was the total ion current area for that peak. These estimates were reported to one significant figure.

3.7 QUALITY ASSURANCE PROGRAM

The purpose of the IRA-F program was to characterize the air quality conditions around the Basin F area following the completion of remedial activities conducted during 1988 and 1989. To assure achievement of this goal, a program integrating quality planning, assessment and improvement was established.

The guidelines for developing the QA program conducted under IRA-F were the policies and procedures outlined in the RMA CQAP Version 1.0 from July 1989. To assure that field procedures were correct and that calibrations were accurate, the QA Program was implemented through the use of scheduled audits of field procedures, QA oversight of laboratory activities, review of field and laboratory results for QC samples, training of personnel in quality issues, corrections of nonconformance, review of control charts and documentation of all QA-related activities.

The above QA procedures were conducted to ensure that the sampling and chemical analyses performed for IRA-F were of appropriate and acceptable quality. The criteria employed to fulfill these QA/QC requirements are described by using the terms of precision, accuracy, completeness, representativeness and comparability. Data quality objectives (DQOs) for IRA-F were developed as part of the QC activities to cover the areas of uncertainty. Field QC samples were collected to assess field sampling efforts for contamination and representative sampling procedures. Laboratory QC samples were in the form of standard matrix spikes that were collected at varying levels within the certified range and were used to assess acceptability of the analytical lot containing samples. (See Section 3.6.1.3 for more detail.)

3.7.1 Responsibilities

The ultimate responsible party for the data collected in support of the IRA-F project was the PMRMA. Responsibilities were then delegated to the Analytical Branch and individual project officers. The EBASCO project manager's responsibilities included organizing a project team and assuring that appropriate controls were implemented and procedures were employed to attain the

goals and objectives of the IRA-F project. The PQAC had the responsibility to establish, oversee and control field and analytical data quality. The PQAC ensured that all procedures were understood and properly implemented, and that results were interpreted correctly.

3.7.2 Project Quality Assurance Plan

The project QA plan, (referred to as the Plan) employed by the IRA-F project included the quality aspects from the CQAP version 1.0, July, 1989 and the EBASCO Quality Assurance Plan (QAP) for RMA projects. The Plan included specific descriptions of how the QA controls were to be implemented for field and laboratory monitoring and measurement data. It also addressed project organization, sample collection, sample custody procedures, instrument calibration and data management.

3.7.3 Documentation

Documentation requirements were included as key project tasks to ensure data validity. Good record keeping practices ensured that quality was maintained and problems were identified and resolved. Under normal practice, accountability for a sample began when a sample was taken from its natural environment. Field and laboratory records traced the sample, procedures, problems and corrective actions from the time the sample was collected to the disposal of the sample extract and the reporting of the data results.

Specific documents were generated, reviewed, corrected and filed in accordance with good practices. Document files included the field data sheets, chain-of-custody forms, calibration forms, audit reports, laboratory control chart submittals and reviews, sample volume computations and data listings. All these records have been stored for easy access for future requirements. In addition a technical analysis of meteorological conditions and potential sources are provided for the selected extreme maximum events. The results are compared to the preceding and concurrent programs, both on-post and off-post. Potential source characterizations are also presented.

4.0 IRA-F SAMPLING RESULTS

This section provides a detailed discussion of the results of the IRA-F Air Monitoring Program. The purpose of this section is to summarize the sampled air concentrations, to provide a comparison to the preceding and concurrent air monitoring programs, to examine the potential causes for the observed concentrations, and to discuss trends and impacts of the concentrations. Separate results are presented in this section for each group of analytes (TSP, PM-10, metals, arsenic, mercury, VOCs, and SVOCs) which were sampled under the routine monitoring program. Another subsection describes the results of the cap and vent monitoring program. For each group of analytes, the IRA-F recovery rates, the observed mean values, 24-hour maximum values, and the number of detections are presented. In addition a technical analyses of meteorological conditions and potential sources are provided for the selected extreme maximum events. The results are compared to the preceding and concurrent programs, both on RMA and off RMA. Potential source characterizations are also presented.

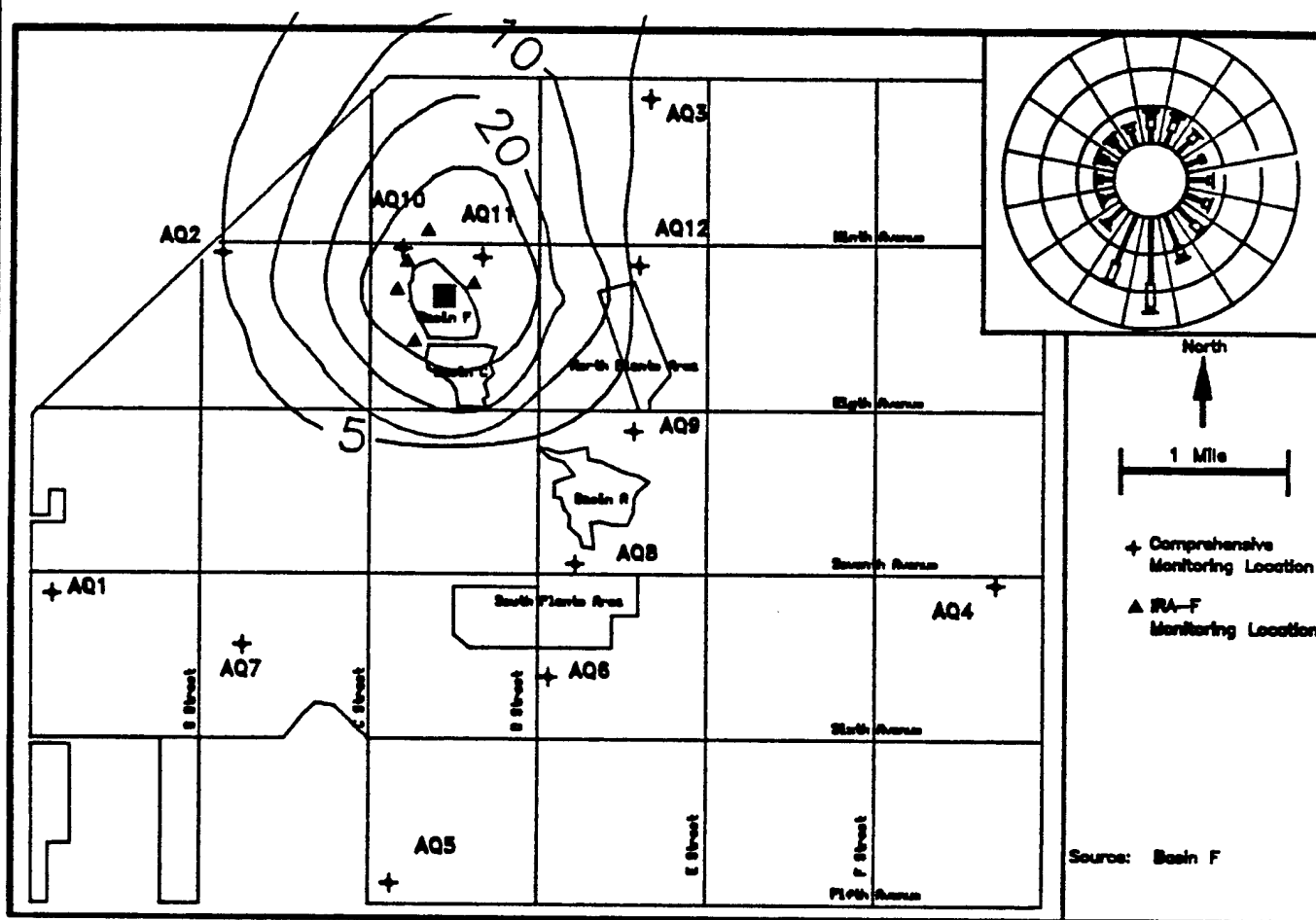
The results must be interpreted in terms of the mean atmospheric dispersion patterns for the IRA-F period of observation. Section 3.4 describes the meteorological monitoring program, which was conducted concurrently under the CMP. The mean dispersion pattern, for an assumed Basin F area source was described in Section 3.4, and depicted in Figure 3.4-1. Generally, the highest impacts occur to the north and northeast of the basin. Meteorological and dispersion conditions for each of the extreme, or worst case, episodes are described in each of the subsections for each group of analytes.

Results from the Basin F Remedial Action program are also discussed. Sampling during that effort was conducted from April 1988 through May 5, 1989. A separate odor sampling program was conducted as a part of both the Remedial Action and the CMP for the period October 1988 to May 5, 1989. The details of these programs are discussed in the Basin F Close-Out Report (EBASCO, 1989) and the Annual Reports for the Air Element of the CMP (Stollar, 1989, 1990). These two programs focused on analysis of samples collected during the projected two worst case days in a given week. Samples were collected on all days with ongoing remedial activities, and

at the conclusion of a week the sample period was reviewed with respect to the meteorological conditions and operational activities. Samples from days with the potentially highest concentrations were selected for analysis based on this review. As a result of this selection process, the mean conditions determined by these programs must be considered very conservative estimates of overall mean conditions. It is very likely that most worst case conditions were captured by this analytical scheme. The special concerns which relate to determining sources or trends based on these three programs are also discussed. Sampling under the CMP was conducted both prior to and during the IRA-F sampling effort. Results are discussed in terms of addressing Basin F area impacts and interpreting IRA-F sampling results.

The Basin F network had been designed specifically to evaluate impacts surrounding the remedial activity during and after cleanup operations. Due to the anticipated changes in ambient air quality during and after the active period of the Basin F cleanup, the analytical results of air quality sampling were grouped into phases. These phases were defined in Section 3.1 as Phase 1 (March 22, 1988, to December 12, 1988); Phase 2, Stage 1 (December 13, 1988, to February 15, 1989); Phase 2, Stage 2 (February 16, 1989, to May 5, 1989); Phase 3 (May 6, 1989, to September 30, 1989) and Phase 4 (October 1, 1989, to September 30, 1990). Appendix B presents a tabular listing of the complete ambient air sampling data sets from all phases of IRA-F. Appendix B-1 includes data from the odor sampling program for Phases 1 and 2. Appendix B-2 contains IRA-F Phase 3 and 4 data. Appendix B-3 contains the field and trip blank analyses.

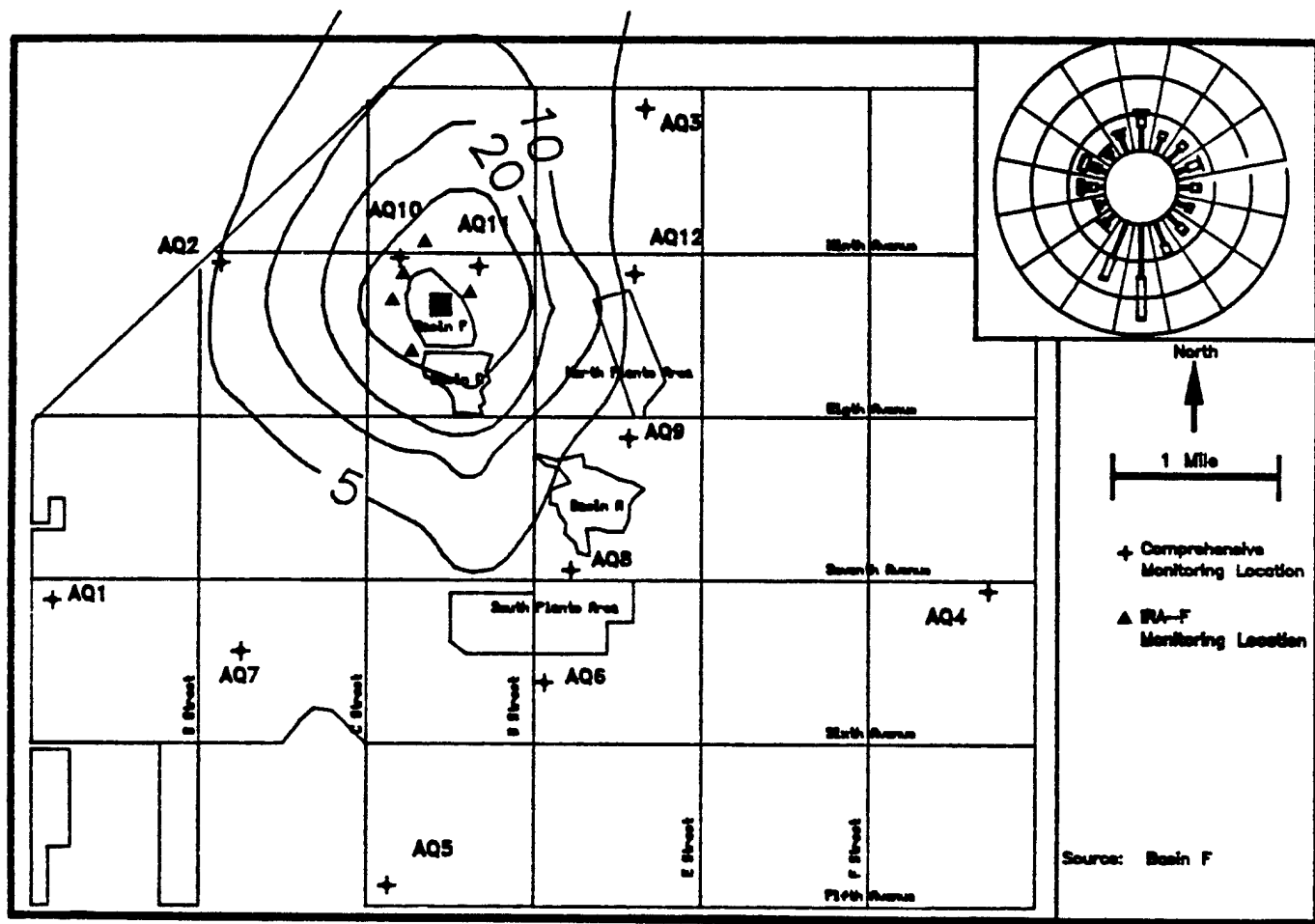
Figures 4.0-1 through 4.0-5 show mean dispersion patterns for a hypothetical source at Basin F during Phases 1 through 4. These dispersion patterns had a direct influence on sampling efforts, and must be considered when interpreting sampling results. The dispersion patterns, or X/Q contours, can best be described as a function which relates ambient concentration (X) to source strength (Q). It thus incorporates all meteorological factors, but does not include any actual source measurements. The X/Q contours were obtained from the EPA ISC model (using Basin F as the hypothetical source area). They reflect the influences of wind speed, wind direction,



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Figure 4.0-1
X/Q Dispersion for Phase 1



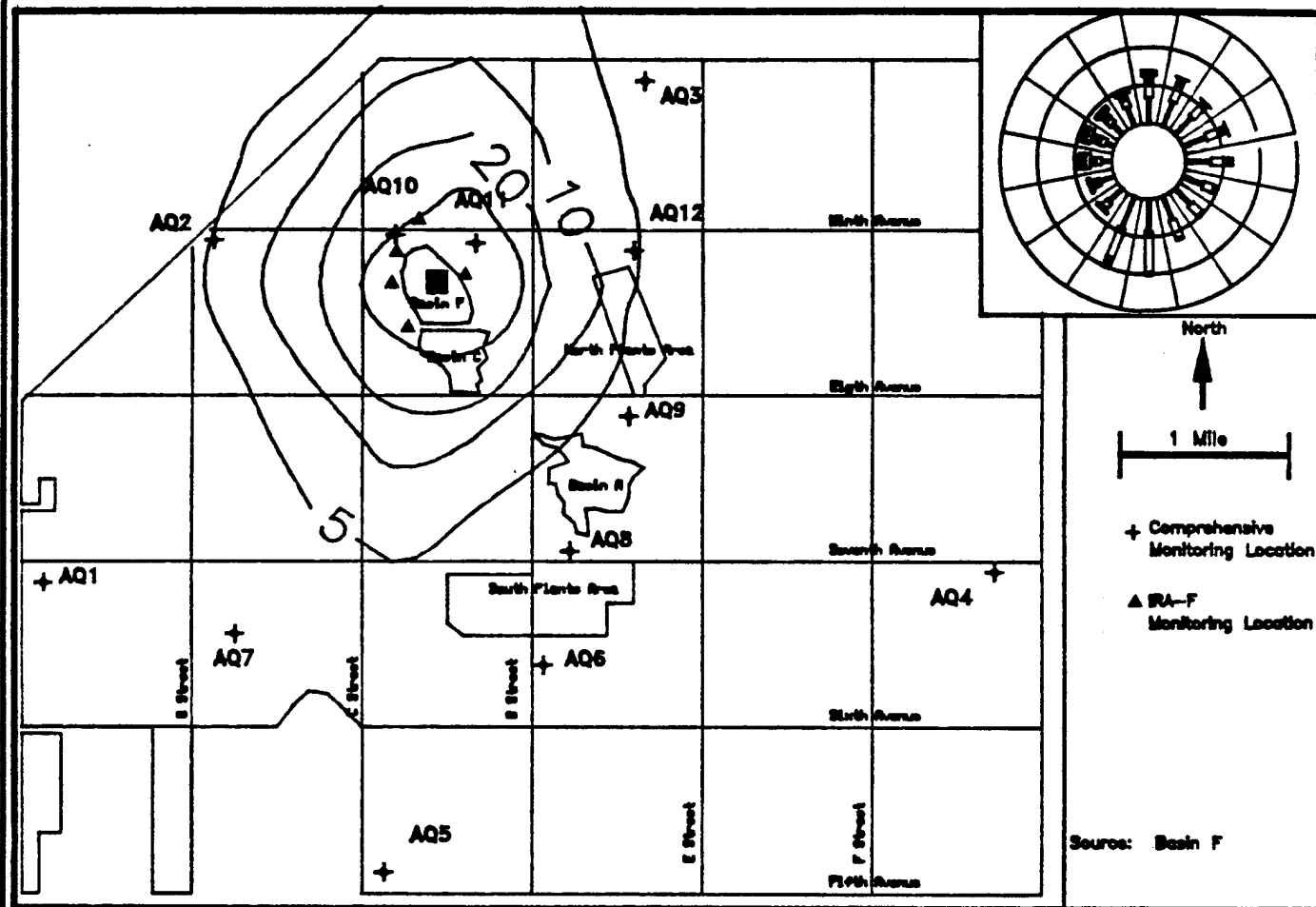
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Figure 4.0-2

X/Q Dispersion for Phase 2, Stage 1

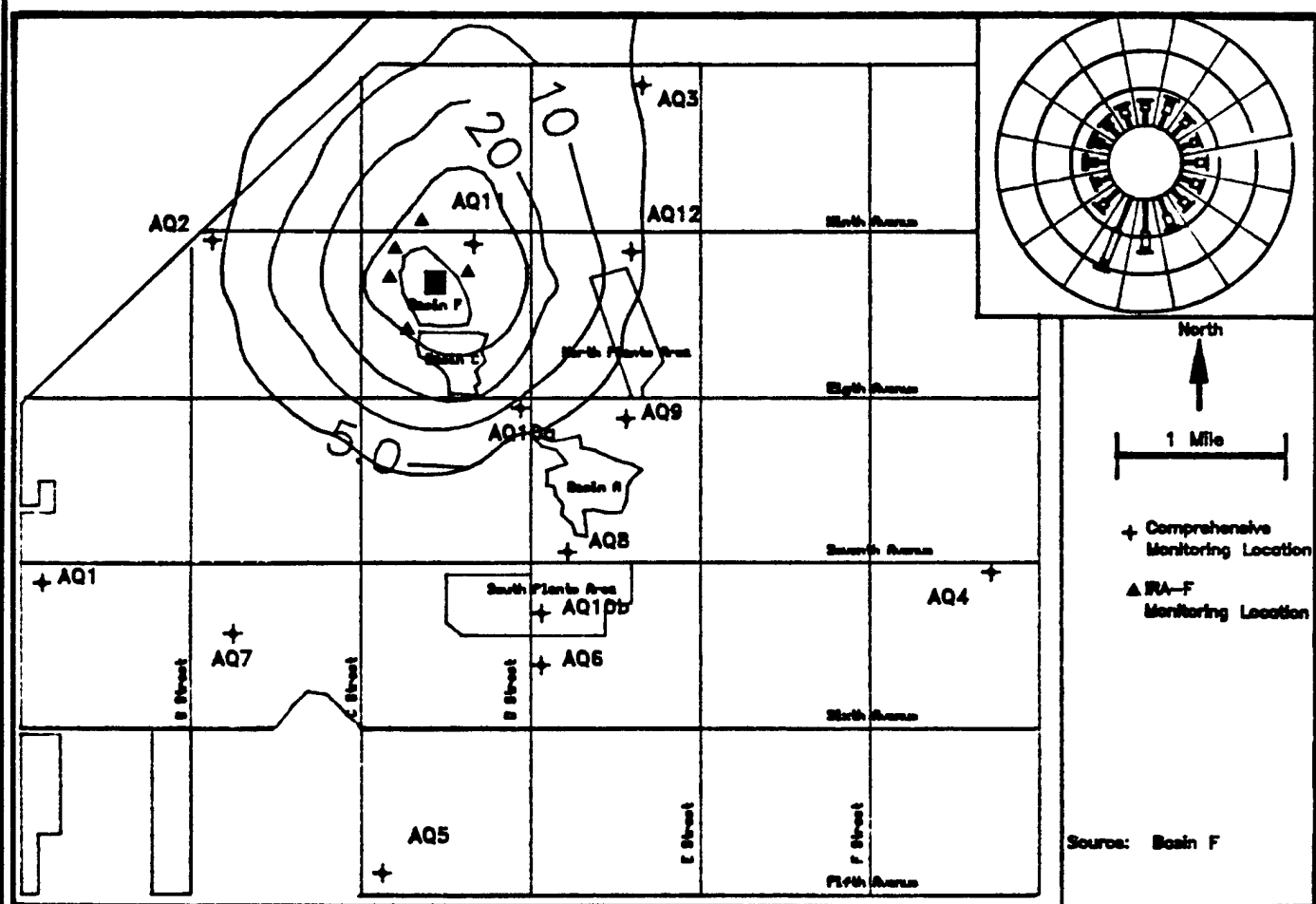


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Figure 4.0-3

X/Q Dispersion for Phase 2, Stage 2



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Figure 4.0-4

X/Q Dispersion for Phase 3

atmospheric stability, and inversion conditions on the spread of pollutants during each phase. The X/Q values do not indicate actual ambient concentrations, but indicate relative strength, or potential for concentration levels, based on meteorological conditions and an unspecified source strength. Nevertheless, actual higher concentration levels generally correspond to higher X/Q when there is a significant source impact. As can be seen during Phases 1 and 2, the higher values were close to the Basin F source and directly downwind from the prevailing wind patterns. The dispersion patterns show a consistent maximum impact to the north of Basin F, reflecting the prevailing wind flow during the monitoring periods. This is clearly shown in the wind rose of each figure. As a consequence of these dispersion and meteorological patterns, the higher concentrations of the potential Basin F source contaminants during remediation activities would be encountered adjacent to Basin F and just north of the basin. Monitoring results for some compounds from FY88 and FY89 remediation periods have substantiated this feature.

The dispersion pattern was similar for Phases 3 and 4, although seasonal variations were evident. The dispersion patterns, in fact were essentially identical for each phase of the remediation and post-remediation periods. The implication, therefore, is that any significant variations in monitoring results were most likely a function of varying source emissions rather than meteorological factors. In particular, any dramatic reduction in ambient concentrations near to and north of Basin F would have to be attributed to a reduction in source emissions.

4.1 TOTAL SUSPENDED PARTICULATES

Levels of TSP at RMA can be attributed to two principal sources: 1) the influx of particulates from the Denver metropolitan area, and 2) remedial activity sources that helped to produce wind-blown dust, particularly during dry episodes, and/or periods of high winds. Total suspended particulates have been sampled from a period well before remedial activity began and through all four phases of Basin F operations. This section describes the recovery of TSP samples under IRA-F, and it includes a summary of all data collected around Basin F during all four phases. Mean and extreme values are cited and individual days with high concentrations, or "high event" days, are discussed as well.

4.1.1 Recovery of TSP Samples

A summary of the recovery percentages of TSP samples for each site during the IRA-F project, is presented in Table 4.1-1. Recoveries were based on the total number of samples planned during the period. Sample losses due to power outages, sampler failure, laboratory errors and other problems were counted as invalid samples. Note that with the exception of site FC-1, all recoveries as well as the overall recovery for all sites were well above 90 percent. The lower recovery at site FC-1, above the EPA target recovery of 75 percent, was due in a large part to a series of power problems at the site during the summer of 1989. A system-wide power outage on August 2, 1989, caused the loss of one sample from each of the "FC" sites.

4.1.2 Mean TSP Concentrations

Geometric mean values, rather than arithmetic means, are commonly used to report TSP sampling values. This standard reporting format was initiated by the EPA, and is applied because TSP monitoring data will fit into a log-normal distribution curve. Under log-normal distribution, there is a relatively large population of low concentrations, and a small population of high concentrations.

Geometric mean TSP concentrations are presented in Table 4.1-2. Note the wide range in mean values in Phases 1 and 2, and narrow range in Phases 3 and 4. In general, each site displayed a trend of decreasing concentrations over time. In Phase 2, at sites BF-2, BF-2D, BF-3, BF-4 and BF-6 the trend for decreasing concentration was broken due to the large disturbed area and intense traffic during transport of clay and topsoil to cap Basin F. In Phases 3 and 4, the highest mean concentrations occurred at FC-5. This is probably due to that site's location on the downwind side of a frequently used gravel road; the other sites were located farther away from roads and other discrete sources of TSP. The lowest concentrations during Phase 3 were at stations BF-5, BF-7, and RIFS1, which were not on the Basin F perimeter. The sites closer to the Basin F perimeter showed higher TSP levels. However, this difference may be attributed to the restricted length of sampling (in May and June 1989 only) at BF-5, BF-7, and RIFS1. Sparse vegetation around the Basin F area was reseeded at the end of Phase 2, which may also explain

Table 4.1-1 Recovery of IRA-F Total Suspended Particulates Samples

STATION	NUMBER OF SAMPLES IN PERIOD	NUMBER OF VALID SAMPLES	RECOVERY PERCENT
FC-1	43	35	81.4
FC-2	43	41	95.4
FC-2D	43	41	95.4
FC-3	43	40	93
FC-4	43	41	95.4
FC-5	40	37	92.5
BF-5	5	5	100
BF-7	5	5	100
RIFS1	5	5	100
All Stations	270	250	92.6

Table 4.1-2 Geometric Mean Total Suspended Particulates Concentrations ($\mu\text{g}/\text{m}^3$)
at Basin F/IRA-F Sampling Locations

STATION	SAMPLING PHASE				
	PHASE 1	PHASE 2 STAGE 1	PHASE 2 STAGE 2	PHASE 3	PHASE 4
FC-1/BF-1	105	78	62	49	39
FC-2/BF-2	122	119	81	39	36
FC-2D/BF-2D	135	190	104	40	37
FC-3/BF-3	68	53	55	44	32
FC-4/BF-4	117	72	80	42	35
FC-5	N/A*	N/A	N/A	54	44
BF-5	64	48	45	31	N/A
BF-6	89	76	109	N/A	N/A
BF-7	47	44	43	32	N/A
RIFS1	N/A	68	56	35	N/A
RIFS2	N/A	46	40	N/A	N/A

* N/A = Site Not Active or not yet established during sampling phase

these patterns. As vegetation became more dense through Phase 4, TSP levels decreased. The lowest mean during Phase 4 was detected at FC-3, which is in the predominantly upwind direction from Basin F in a relatively thickly vegetated area.

For a visual illustration of mean and maximum concentrations throughout the monitoring Phases 1 through 4, refer to Figure 4.1-1 which presents a graphical depiction of the trends in mean and maximum TSP concentrations by site, by phase. Table 4.1-3 provides definitions of codes and abbreviations used on this figure and the remainder of the Section 4 graphs. On this graph, as well as on other graphs for other compounds, in ensuing sections, the site designations FC-1 through FC-4 include data from sites BF-1 through BF-4 for time periods when those site identifications are applicable.

The geometric mean TSP concentration from the site FC-1/BF-1 was $105 \mu\text{g}/\text{m}^3$ during Phase 1. The mean dropped to $78 \mu\text{g}/\text{m}^3$ during Phase 2, Stage 1, then again to $62 \mu\text{g}/\text{m}^3$ during Stage 2. In Phase 3 the mean had declined to $49 \mu\text{g}/\text{m}^3$, and finally to $39 \mu\text{g}/\text{m}^3$ during Phase 4. The highest TSP concentrations during the remediation period were recorded at FC-2/BF-2. This site was at the northeast perimeter of the Basin F compound, downwind of the prevailing wind flow and in close proximity to extensive earthmoving activities. The geometric mean TSP concentration at this site was $122 \mu\text{g}/\text{m}^3$ during Phase 1, $119 \mu\text{g}/\text{m}^3$ during Phase 2, Stage 1, $81 \mu\text{g}/\text{m}^3$ during Stage 2. Concentrations dropped off to $39 \mu\text{g}/\text{m}^3$ during Phase 3 and finally to $36 \mu\text{g}/\text{m}^3$ in the Phase 4 post-remedial period. Station FC-3/BF-3, at the southern perimeter of the former Basin F measured decreasing geometric mean TSP concentrations of $68 \mu\text{g}/\text{m}^3$ in Phase 1; $53 \mu\text{g}/\text{m}^3$ in Phase 2, Stage 1; $55 \mu\text{g}/\text{m}^3$ in Phase 2, Stage 2; $44 \mu\text{g}/\text{m}^3$ in Phase 3 and $32 \mu\text{g}/\text{m}^3$ in Phase 4.

4.1.3 Maximum Total Suspended Particulates Concentrations

Table 4.1-4 presents the 24-hour maximum concentrations, by phase, at each site. Similar to the mean concentrations, there were wide ranges of maximum levels during Phases 1 and 2. The highest maximums during Phase 1 ($902 \mu\text{g}/\text{m}^3$ and $430 \mu\text{g}/\text{m}^3$) and the highest concentrations

Table 4.1-3 Definition of Codes and Abbreviations Used on Section 4 Graphs of Analyte Concentrations

Site Code	Site Name	Site Redesignated for IRA-F	Used in Phase(s)
FC1	FC-1 or BF-1	Yes	1, 2, 3, 4
FC2	FC-2 or BF-2	Yes	1, 2, 3, 4
FC3	FC-3 or BF-3	Yes	1, 2, 3, 4
FC4	FC-4 or BF-4	Yes	1, 2, 3, 4
BF5	BF-5	No	1, 2, 3
FC5	FC-5	New	3, 4
BF6	BF-6	No	1, 2
BF7	BF-7	No	1, 2, 3
RIFS1	RIFS1	No	1, 2, 3
RIFS2 ^a	RISF2	No	2

Phase Code	Phase
P1	Phase 1
P2-S1	Phase 2, Stage 1
P2-S2	Phase 2, Stage 2
P3	Phase 3
P4	Phase 4

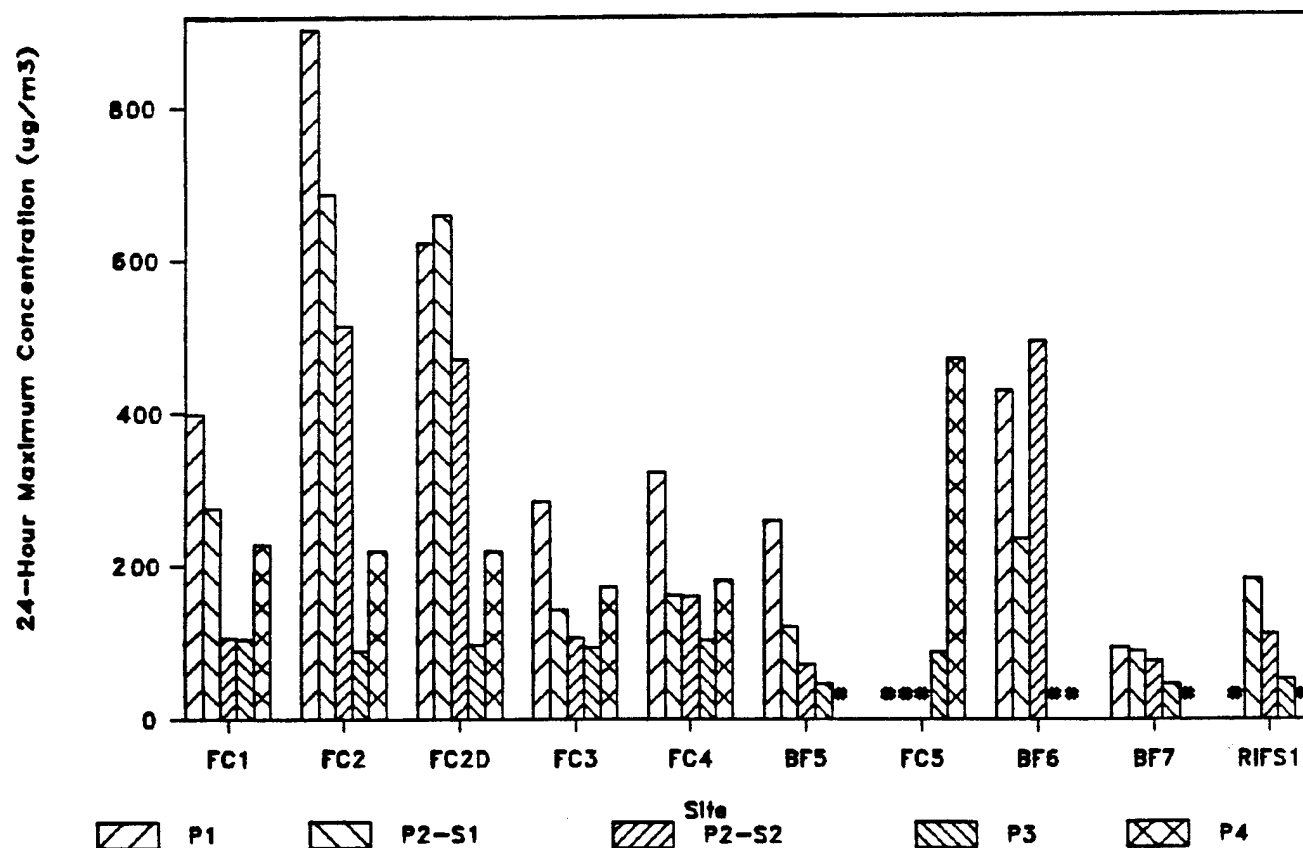
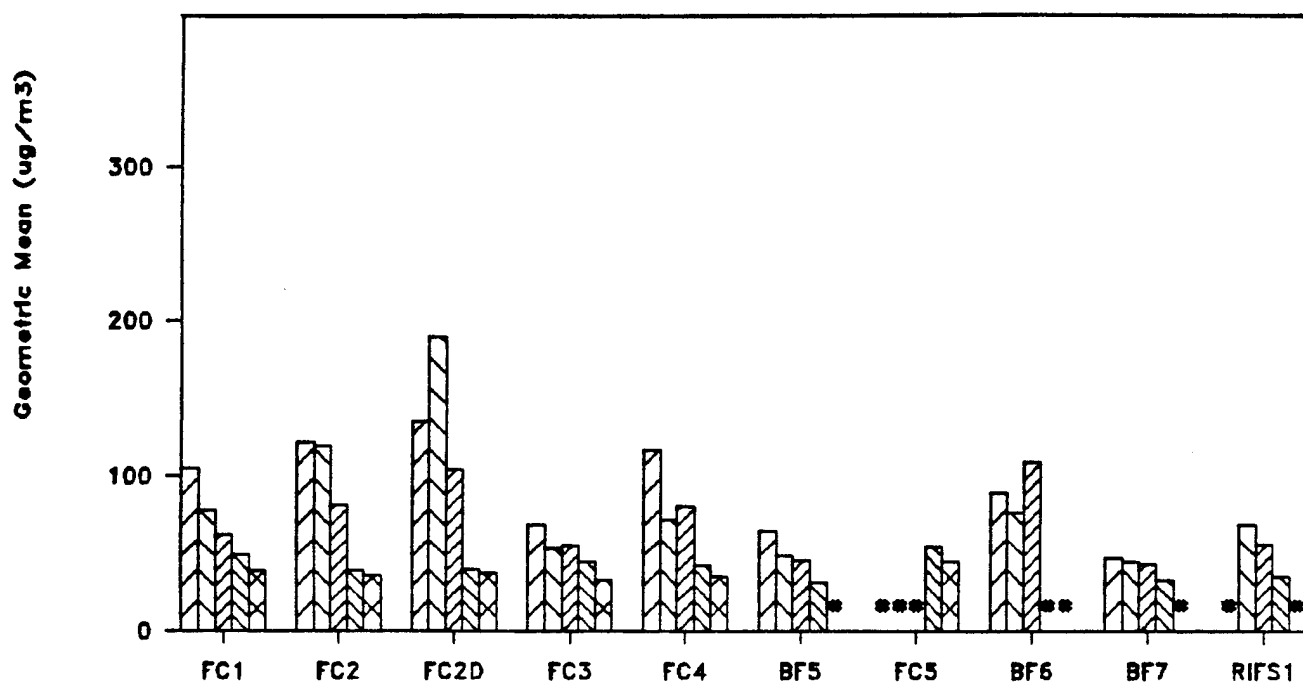
Symbol or Abbreviaiton

$\mu\text{g}/\text{m}^3$ = microgram of analyte per cubic meter of air sampled

* = Not detected this phase

= Not a target analyte this phase

a = Included for reference, not on graphs



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Figure 4.1-1

Mean and Maximum Concentrations for Total
Suspended Particulates by Site, by Phase

#Not an Analyte This Phase

Table 4.1-4 24-Hour Maximum TSP Concentrations ($\mu\text{g}/\text{m}^3$) at Basin F/IRA-F Sampling Locations

STATION	SAMPLING PHASE				
	PHASE 1	PHASE 2 STAGE 1	PHASE 2 STAGE 2	PHASE 3	PHASE 4
FC-1/BF-1	399	276	107	105	227
FC-2/BF-2	902	687	514	89	220
FC-3/BF-3	286	143	107	94	173
FC-4/BF-4	324	162	160	103	181
FC-5	N/A*	N/A	N/A	87	471
BF-5	260	120	71	46	N/A
BF-6	430	236	493	N/A	N/A
BF-7	94	89	76	45	N/A
RIFS1	N/A	183	111	52	N/A
RIFS2	N/A	121	77	N/A	N/A

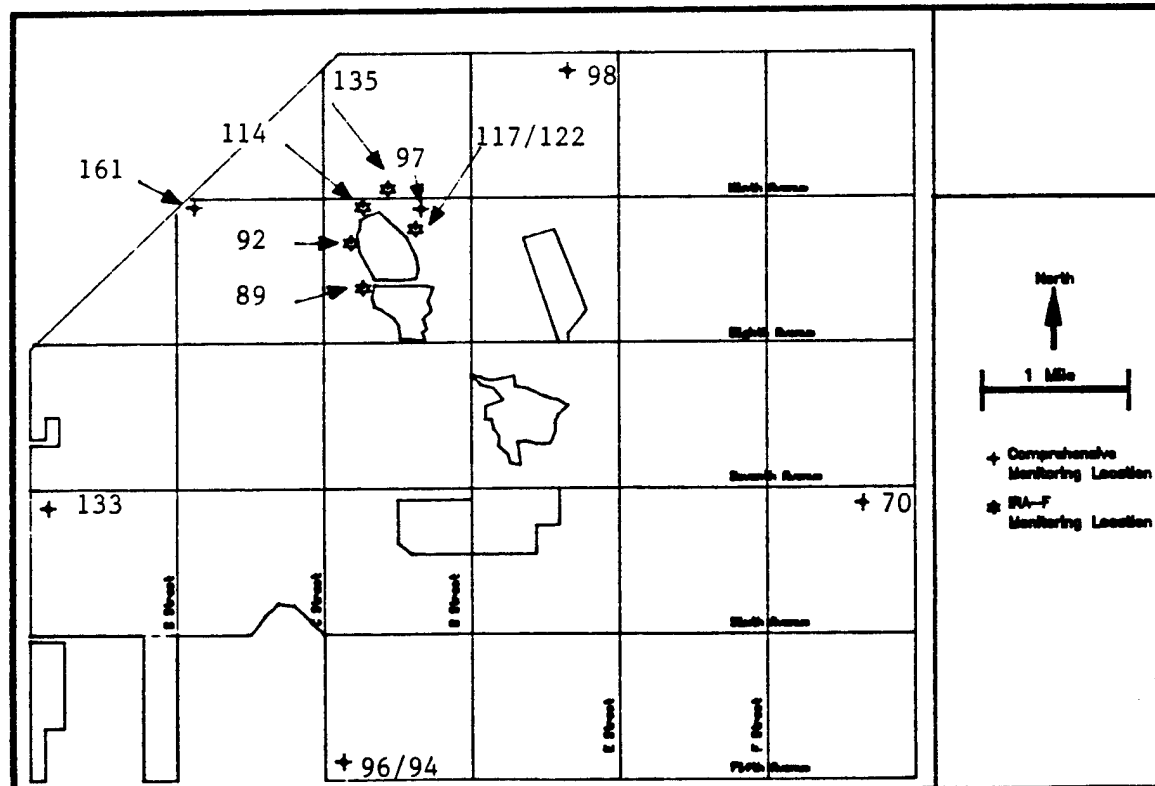
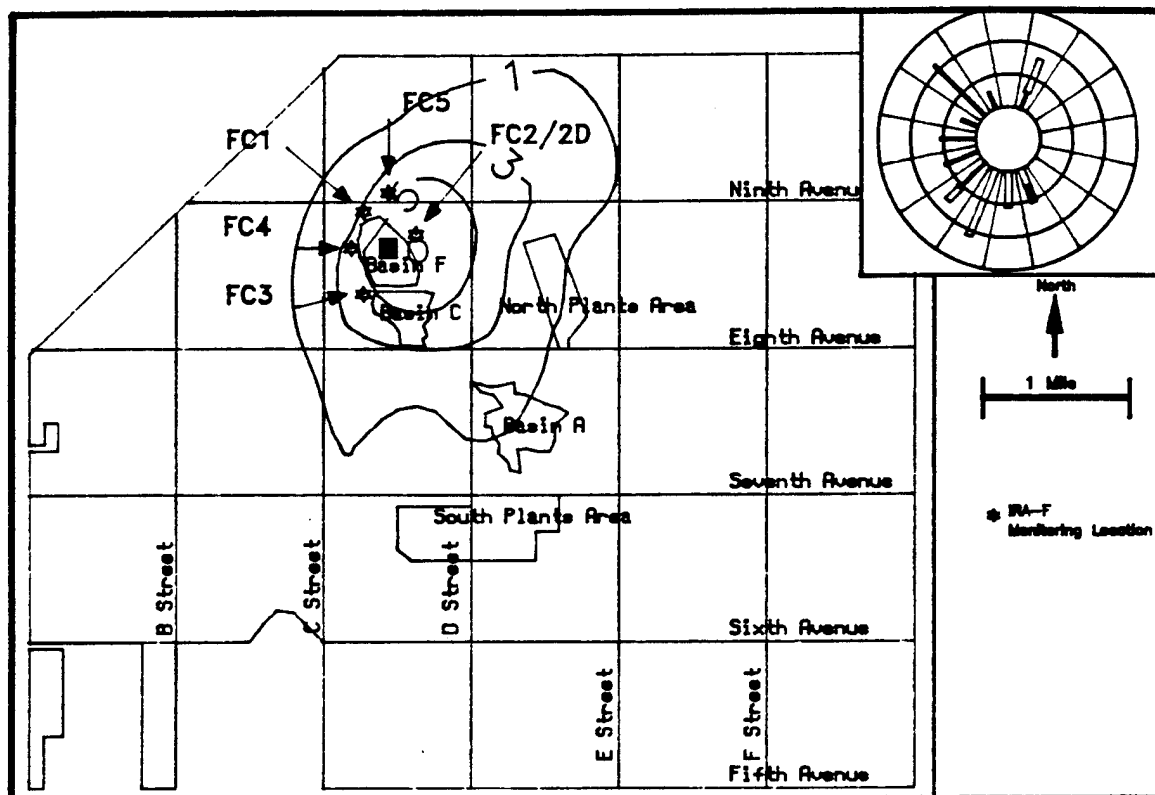
* N/A = Site Not Active or not yet established during sampling phase

during Phase 2 were ($687 \mu\text{g}/\text{m}^3$ and $493 \mu\text{g}/\text{m}^3$) at sites BF-2 and BF-6, respectively. Both of these sites were adjacent to the principal truck routes over which clay and dirt were hauled to Basin F. During Phase 3, FC-1 recorded the greatest maximum of $105 \mu\text{g}/\text{m}^3$. During Phase 4, most sites recorded the highest 24-hour maximum for the phase on the same day, September 14, 1990, which was a day of extremely high TSP concentrations recorded at all RMA sites. The September 14, 1990 extreme event is discussed below. Aside from this one day, the next highest overall maximum level during Phase 4 was $135 \mu\text{g}/\text{m}^3$ at FC-5.

It is important to note that individual daily impacts of any substance (TSP, PM-10, metals, VOC, and SVOC/OCP) vary to some extent depending upon the specific meteorological conditions. Two days from Phase 4 were selected for discussion under this section. Both days exhibited high 24-hour TSP concentrations. One site on one day exceeded the federal and state ambient air quality primary 24-hour maximum standards. Since one exceedance per year is allowed at each site, the former Basin F area was in compliance with the ambient TSP standards. Other selection criteria included such appropriate meteorological conditions as moderate winds and dry surface conditions. The results were matched with the dispersion patterns of the corresponding 24-hour sampling periods to correlate the observed results with the theoretical dispersion.

4.1.3.1 Total Suspended Particulate High Event: October 25, 1989

October 25, 1989, characterized a typical day with high particulate levels. Figure 4.1-2 shows the X/Q dispersion pattern, the corresponding wind rose, the reported IRA-F TSP concentrations and the pertinent CMP TSP concentrations for the day. Winds were moderately gusty from the southwest in the early morning hours, then from the west to northwest until noon. At noon the winds switched back to southwest and exceeded 10 mph for two hours before developing a northerly component and dropping to lower speeds. Strong south to southeast winds were present the last 3 hours of the day. As has been typical of high particulates days at RMA, wind speeds during several hours exceeded 10 mph and, notably, the gusty winds were largely from the south to southwest. Ground surface conditions were dry, with no measurable precipitation in the previous 9 days. Of the IRA-F sites, FC-5, downwind of the former Basin F and a nearby gravel



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Figure 4.1-2

X/Q Dispersion Pattern, Wind Rose and TSP
Concentrations for October 25, 1989

($\mu\text{g}/\text{m}^3$)

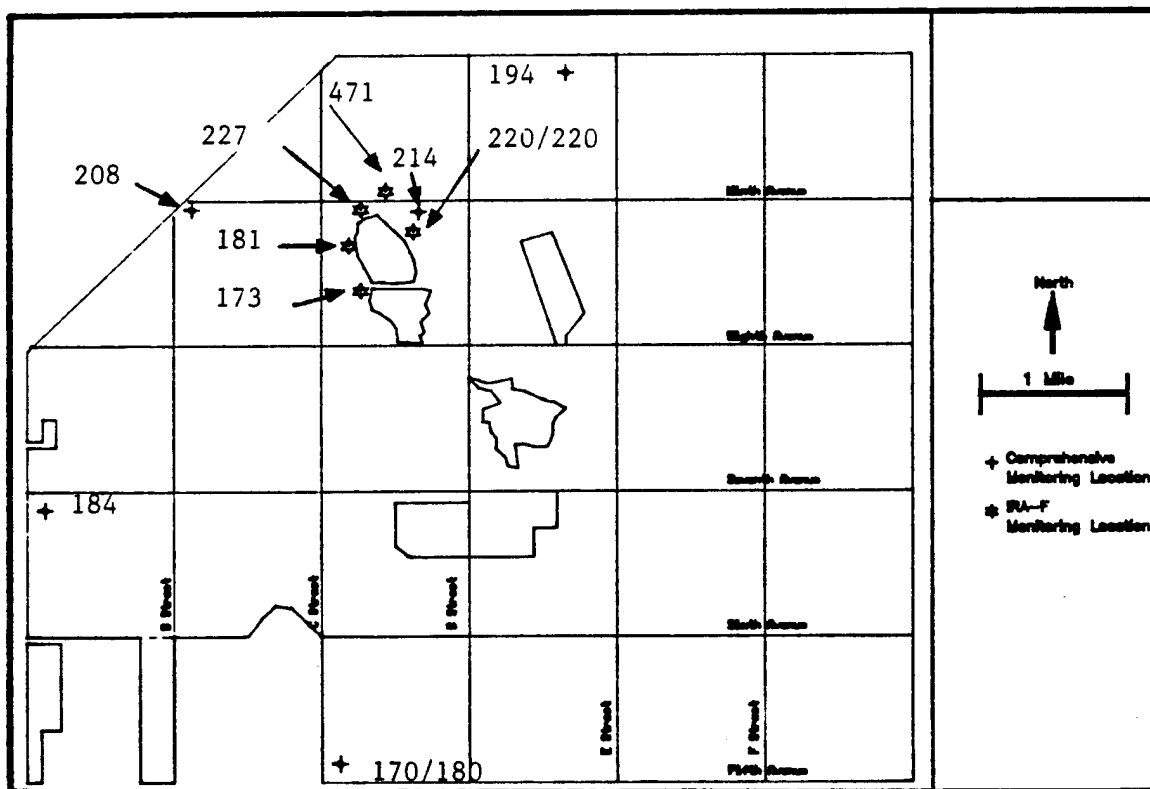
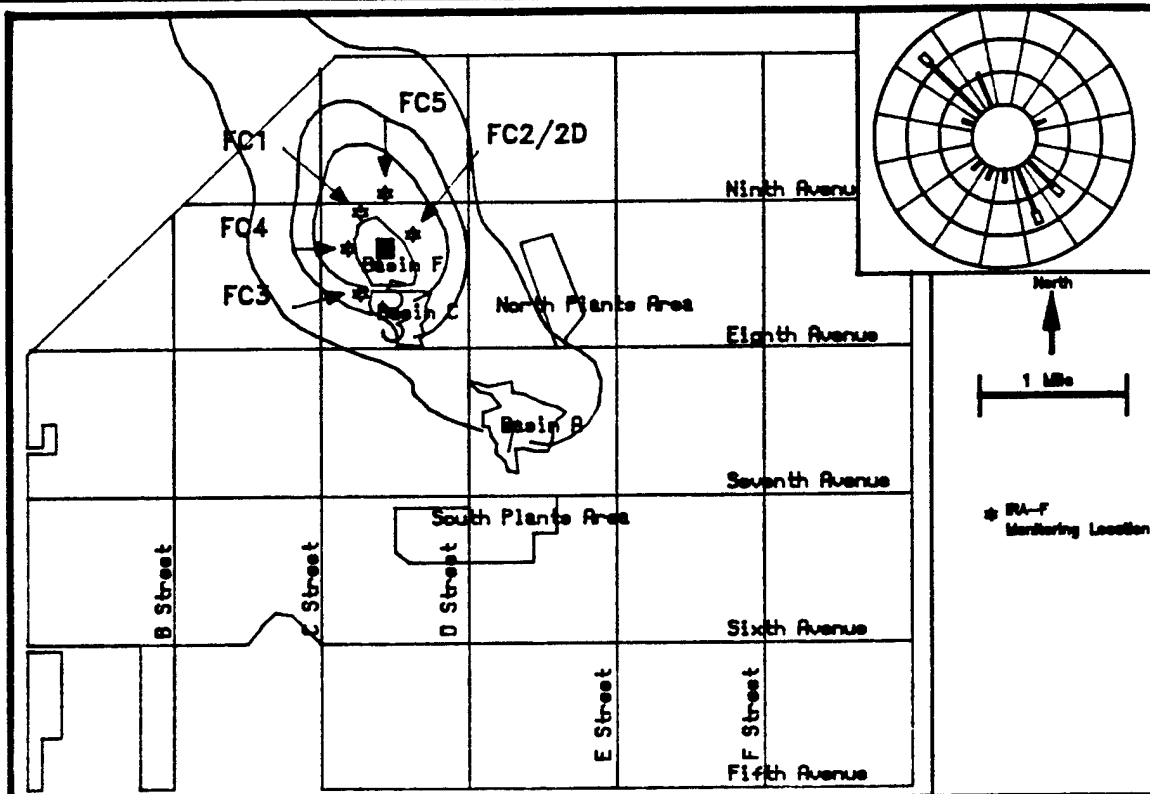
road, during the gusty periods recorded the highest TSP concentration of $135 \mu\text{g}/\text{m}^3$, but CMP sampler AQ2, an RMA western boundary site, recorded $161 \mu\text{g}/\text{m}^3$. Site AQ1, another CMP western boundary site also recorded a high concentration of $133 \mu\text{g}/\text{m}^3$. The collocated IRA-F samplers FC-2 and FC-2D, downwind of the former Basin F, had concentrations of $117 \mu\text{g}/\text{m}^3$ and $122 \mu\text{g}/\text{m}^3$, respectively. Site FC-1, also downwind from Basin F, detected $114 \mu\text{g}/\text{m}^3$. The remainder of the IRA-F and CMP sites all recorded concentrations greater than average.

The day, in general, had very high particulate concentrations recorded across the Denver metropolitan area. Photographs taken by the CMP on that day confirmed the presence of a brown cloud and the resulting reduced visibility. This brown cloud traversed RMA from south to north, then north to south as the day progressed, in the typical diurnal drainage pattern commonly experienced in the Denver metropolitan area. The sampling sites immediately downwind of the former Basin F during the gusty periods recorded higher particulates than some other sites, but the RMA boundary sites upwind of the basin recorded even higher particulates concentrations. It is evident that while there may have been a local influence from the Basin F area, the effects of the Basin F source could not be detected at the northern boundary site AQ3, where the TSP levels were approximately equivalent to those in several other parts of RMA.

Because some of the highest particulates levels were recorded at sites that were not downwind of the former Basin F, it is apparent that the high particulates impacts were from a source which was off site. The Basin F remediation effort by this time had stabilized the local TSP sources, and suspension by mechanical means due to ongoing remediation activity had effectively ceased. Vegetation had started to grow, but a better vegetative cover developed during the following year. The results from this event clearly indicate that non-RMA sources are responsible for the extreme maximum TSP levels.

4.1.3.2 Total Suspended Particulates High Event: September 14, 1990

September 14, 1990, produced unusually high particulates throughout the Denver metropolitan area, RMA, and a good portion of eastern Colorado. Figure 4.1-3 shows the X/Q dispersion



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Figure 4.1-3

X/Q Dispersion Pattern, Wind Rose and TSP
Concentrations for September 14, 1990

($\mu\text{g}/\text{m}^3$)

pattern, the corresponding wind rose, and the reported IRA-F TSP concentrations for the day. Several separate atmospheric inversion layers at various altitudes, combined with light winds, caused limited vertical mixing, thus creating the conditions that encourage development of a high pollution day. Until late morning, winds were from the south-southeast, changing to north-northwesterly around 10:00 a.m. Mountain Standard Time (MST), then returning to the south-southeasterly in the late evening. Wind speeds remained low the entire day. The ground surface was dry, as the most recent rainfall was a trace on September 5, 1990. A heavy haze throughout the area completely obscured the mountains and the brown cloud was very evident from south to north along the foothills.

The highest TSP concentration at RMA, recorded at FC-5, was $471 \mu\text{g}/\text{m}^3$. This was the only pollutant concentration among all the Phase 4 extreme events that exceeded federal and state ambient air quality standards. While this event did produce TSP concentrations that exceeded the standards, it technically did not lead to a violation; the standards allow TSP concentrations to exceed limit values one time per calendar year. It should be noted that since this one result is more than twice the next highest result, the accuracy of this value may be in question. Neither this site, nor the one with the next highest value, was downwind of a local source of particulates during the day, however, FC-5 was very close to a heavily traveled gravel road, and may have been impacted by passing traffic. Metals results for this site, which were obtained from the same filter were not double the concentrations from other sites, in fact some were lower. A TSP concentration of $227 \mu\text{g}/\text{m}^3$ was detected at FC-1, which was downwind of the former Basin F for half the day. Collocated sites FC-2 and FC-2D both recorded concentrations of $220 \mu\text{g}/\text{m}^3$. The remaining IRA-F sites and all CMP sites had TSP concentrations much higher than the RMA average. While the majority of the CMP sites had somewhat lower TSP concentrations than the IRA-F sites, it is difficult to draw conclusions from the variability of extreme data.

September 14, 1990 was a high pollution day for much of Colorado due to the meteorological conditions which persisted throughout the day. The effect on RMA was exacerbated by the proximity of RMA to the Denver metropolitan area particulate sources and the typical diurnal

drainage wind flow pattern. This particular poor air quality day was analyzed in depth in the FY90 Air Quality Data Assessment Report (Stollar, 1990).

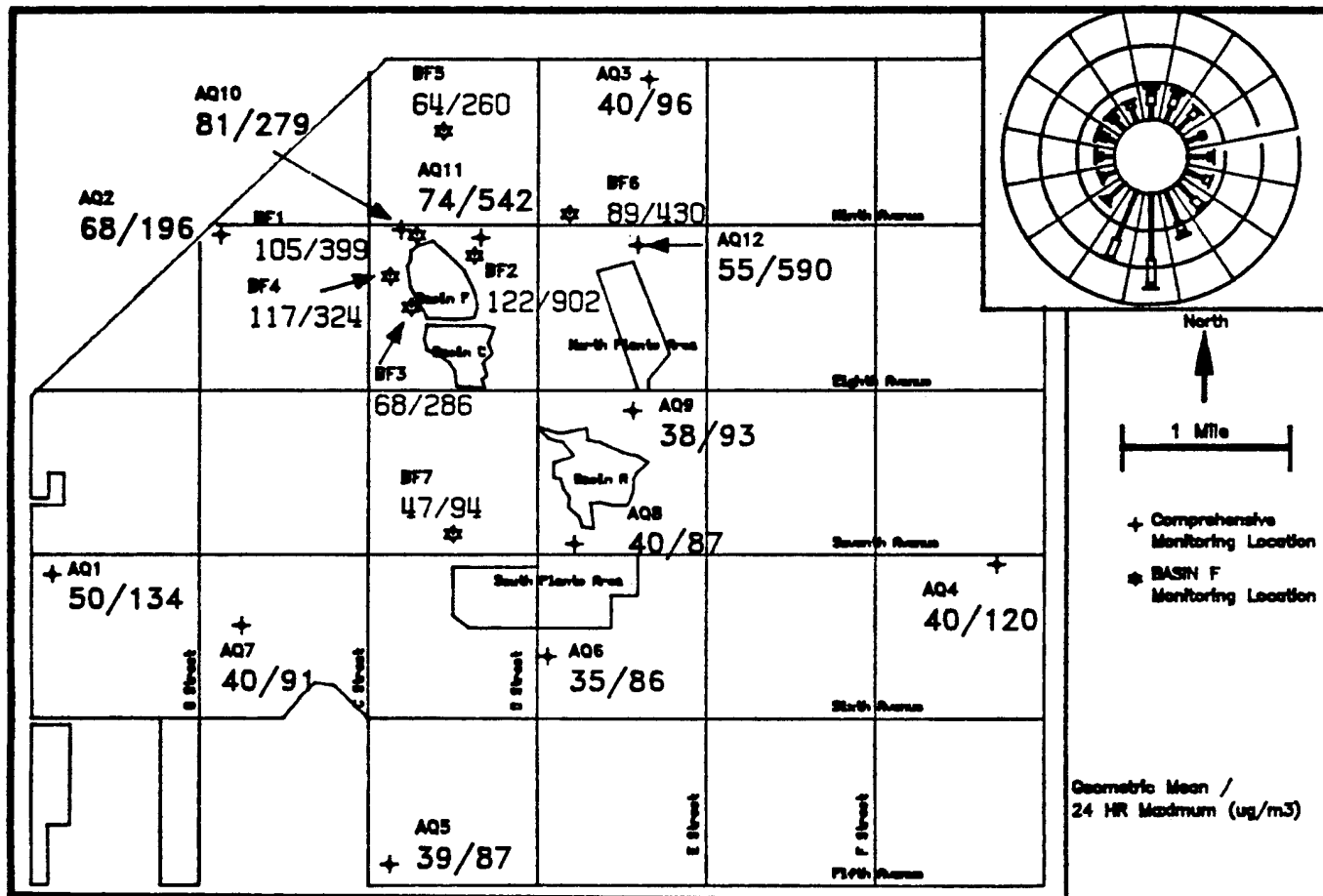
Evaluation of the meteorological conditions and the sampling results leads to the conclusion that neither the former Basin F, nor other parts of RMA, contributed to the high particulates conditions of the day. Impacts upon the RMA were probably due to outside emissions.

4.1.4 Comparison With Other Local Total Suspended Particulates Data

The results of TSP monitoring around the former Basin F have been combined with CMP air monitoring data to illustrate the patterns of TSP concentrations over time from Phase 1 through Phase 4. Figures 4.1-4 through 4.1-8 illustrate the combined sampling results from IRA-F and the CMP from Phase 1 through Phase 4, respectively. These figures demonstrate the significant decrease in TSP concentrations between active remediation and post-remediation periods. At all locations mean concentration levels dropped significantly during Phase 3, the post-remedial period, although 24-hour maximums near Basin F were often still elevated.

The TSP impact during Phase 1 was substantial at locations in close proximity to Basin F remediation activity. The highest geometric mean recorded during this time was $122 \mu\text{g}/\text{m}^3$ at BF-2, while the more distant CMP sites showed average geometric means in the range of $35 \mu\text{g}/\text{m}^3$ to $40 \mu\text{g}/\text{m}^3$ over this period. It is significant to note, however, that on January 2, 1989, during the capping operations an overall maximum 24-hour TSP value of $738 \mu\text{g}/\text{m}^3$ was measured at AQ11 which was adjacent to the Basin F activities. In Phases 3 and 4, however, with cessation of remediation and subsequent reseeded, the impacts were reduced to levels comparable to the CMP boundary monitoring sites.

Individual site impacts reflect the distance from the remedial activities on ambient TSP levels. For example, FC-1/BF-1, located at the north end of the basin, showed the highest levels during the full remediation activity of Phase 1 and then dropped off to typical RMA baseline levels by the conclusion of remediation work. The drop to typical RMA baseline levels at all Basin F



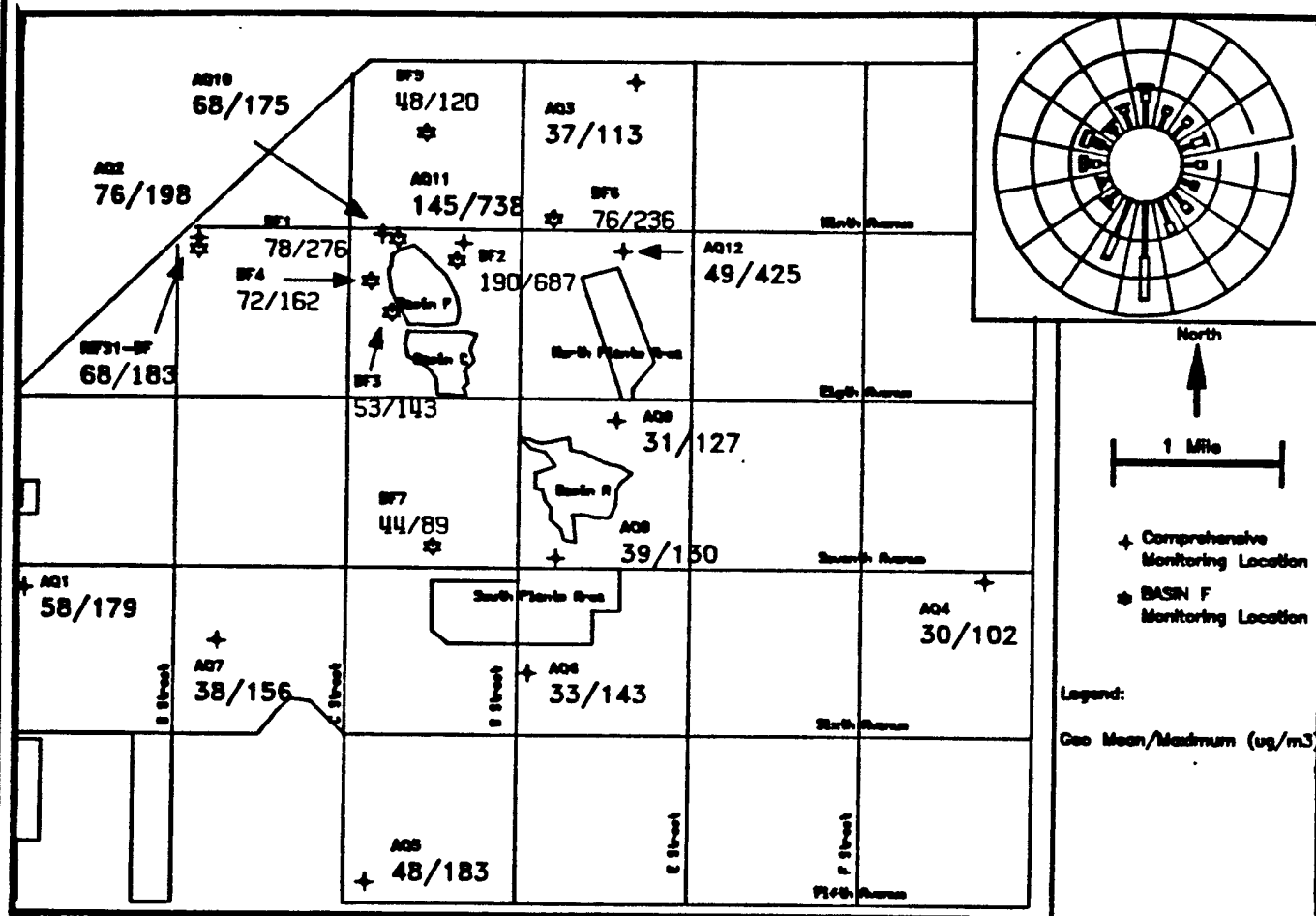
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Figure 4.1-4

Composite TSP Analysis for Phase 1
Combined IRA-F and CMP Data



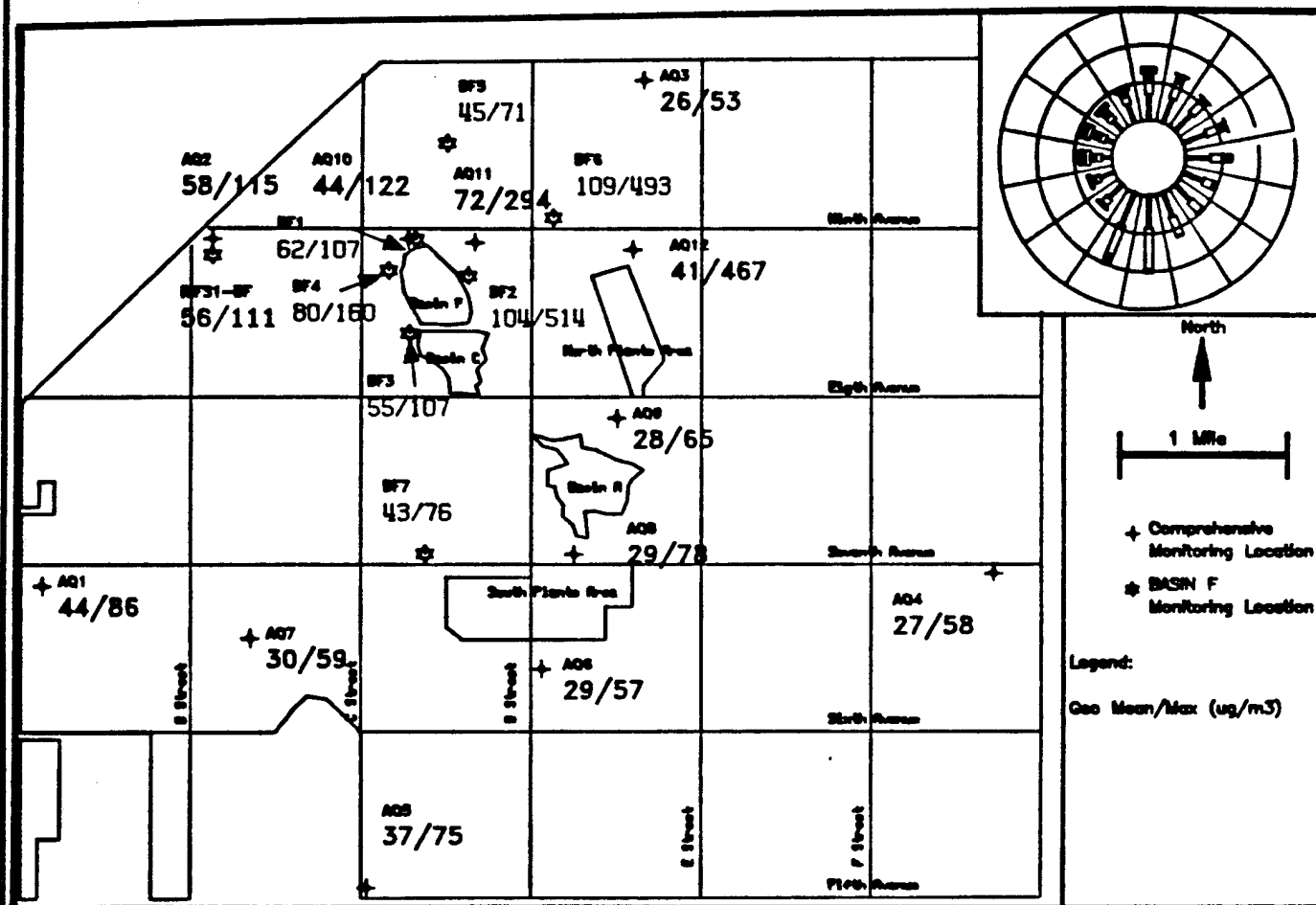
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Figure 4.1-5

Composite TSP Analysis for Phase 2, Stage 1
Combined IRA-F and CMP Data



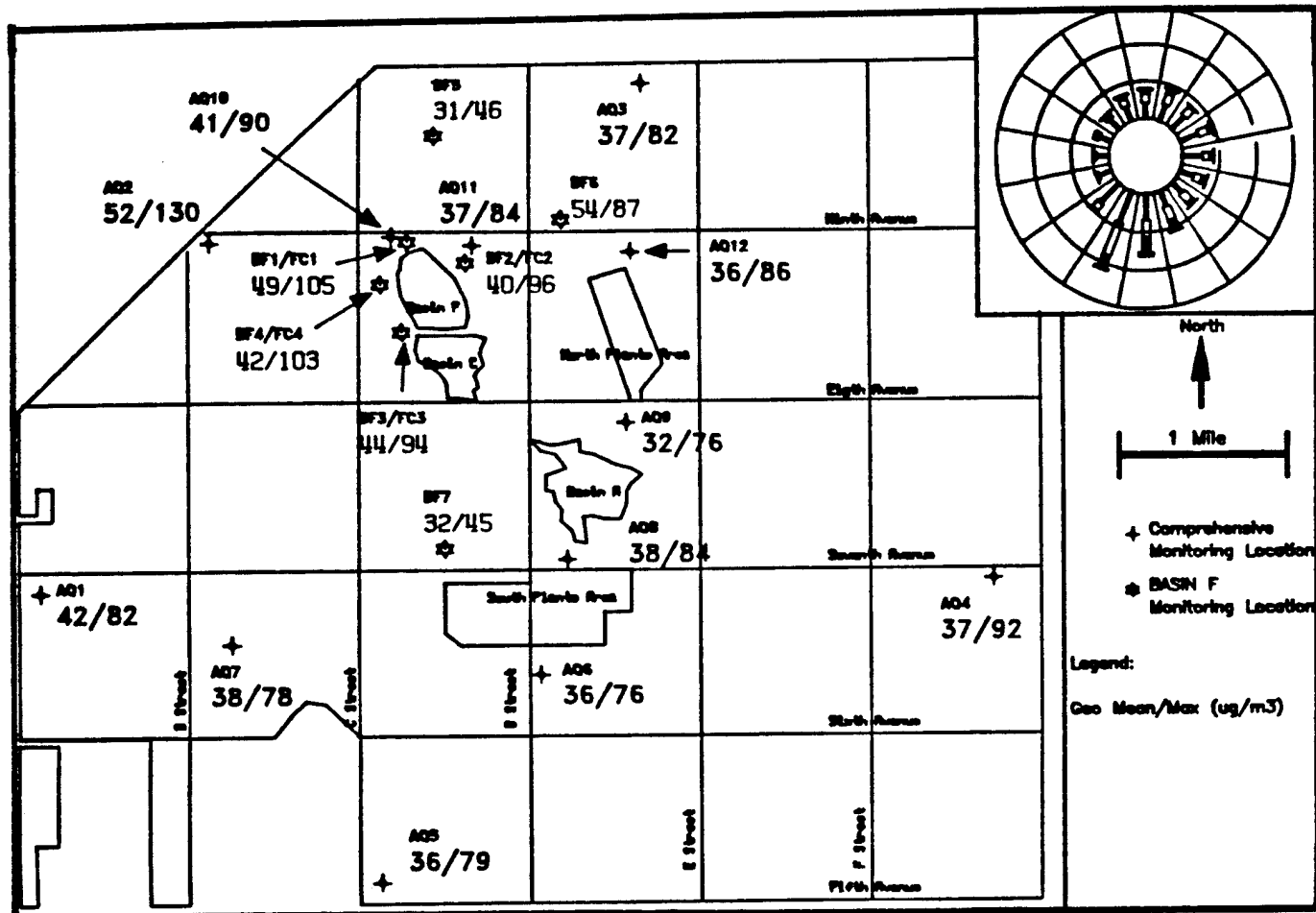
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Figure 4.1-6

Composite TSP Analysis for Phase 2, Stage 2
Combined IRA-F and CMP Data



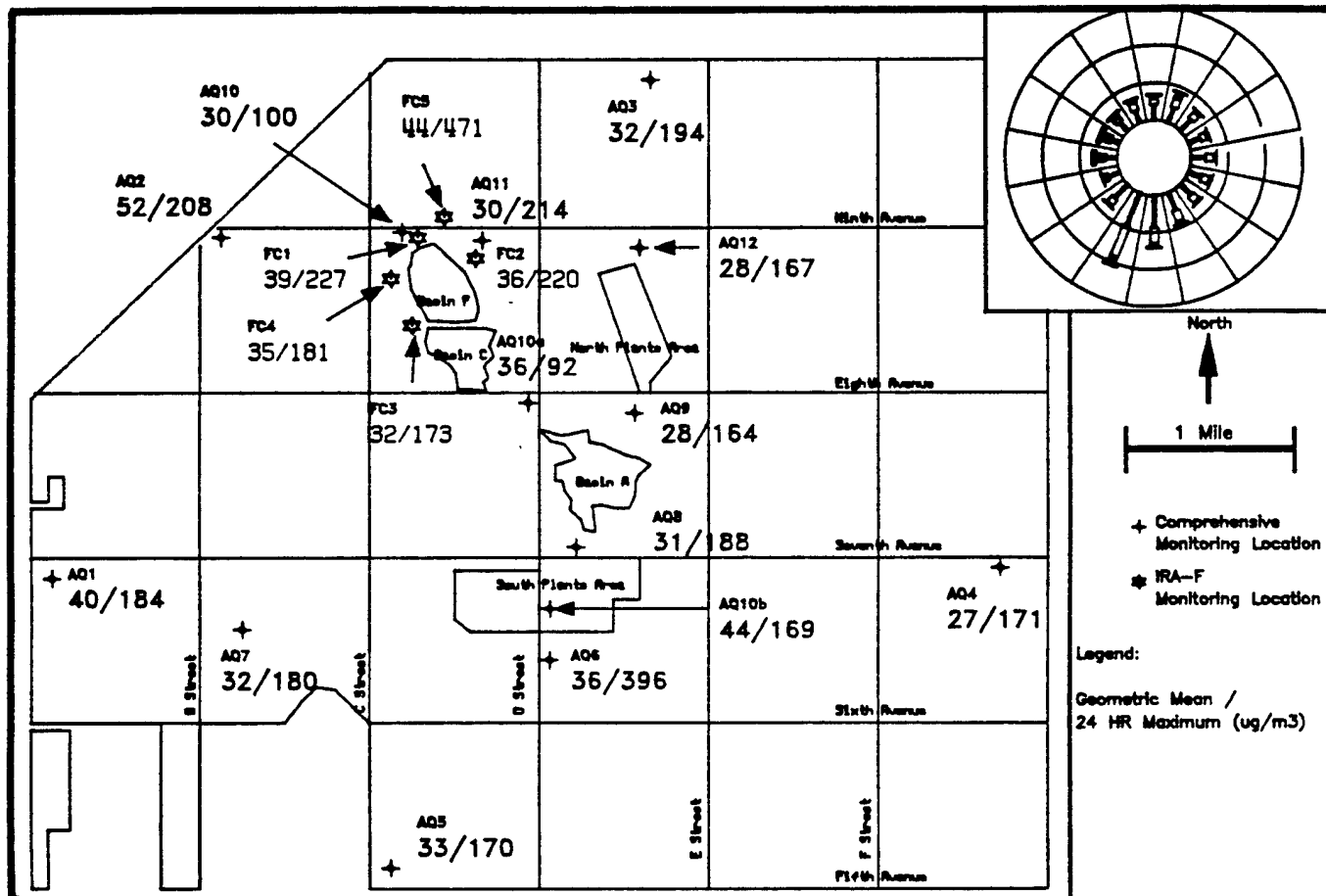
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Figure 4.1-7

Composite TSP Analysis for Phase 3
Combined IRA-F and CMP Data



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Figure 4.1-8

Composite TSP Analysis for Phase 4
Combined IRA-F and CMP Data

monitoring sites occurred during Phase 3. These levels remained at baseline during Phase 4 monitoring as well. To further confirm the reduction of the former Basin F as a TSP source during Phase 4, CMP site AQ2, located on the northwest boundary of RMA, registered the highest TSP concentrations. This result was consistent with patterns established during the RI program (ESE, 1988).

It is significant to note that CMP results (Stollar, 1989, 1990, 1991) clearly reinforce IRA-F data that show a decline in TSP through the progression of the remediation phases. The CMP sites AQ10 and AQ11, which were immediately downwind from Basin F and AQ12 which was adjacent to the borrow pit which supplied the bulk of the of the clay and soil during earth moving activities, showed high TSP levels during Phases 1 and 2 of remediation. After the major portion of the earthmoving activity was accomplished, Phases 3 and 4 demonstrated significant corresponding decreases in TSP concentrations at these sites. Other CMP locations within the interior of RMA showed little variation in geometric means throughout the duration of remedial activity. In contrast, AQ1 and AQ2, which are located on the western boundary nearest to the Denver metropolitan area and the freeway system, exhibited moderately high TSP concentrations throughout the remediation program. Except during the fall and winter of 1989-1990, the Denver metropolitan area data collected by CDH (Stollar, 1989, 1990, 1991) showed normal trends in TSP levels throughout Basin F remediation. During this time period, however, a decline in TSP was noted throughout the Denver metropolitan area and was reflected in the combined RMA air quality data. This particular fall through winter span experienced less severe inversion and brown cloud conditions than normal. Based upon historical data for the Denver vicinity, this lower area-wide TSP trend is considered to be an anomaly.

The highest TSP levels outside RMA were in downtown Denver at the CDH CAMP station, where ambient standards have been exceeded for the past 15 years. During 1989, maximum 24-hour TSP concentrations in downtown Denver frequently exceeded the standard of $150 \mu\text{g}/\text{m}^3$. A maximum of $472 \mu\text{g}/\text{m}^3$ was recorded at CAMP on January 4, 1989. During FY90, the annual geometric mean at CAMP was $101 \mu\text{g}/\text{m}^3$, well above the annual secondary standard of $60 \mu\text{g}/\text{m}^3$.

The maximum 24-hour TSP concentration was $363 \mu\text{g}/\text{m}^3$, which also exceeded the 24-hour primary and secondary standards. Other Denver stations also exceeded the 24-hour and annual standards. As a general rule, TSP concentrations fell off with increased distance from downtown Denver, and were usually recorded at about 50 percent lower in the surrounding suburbs and at RMA.

One important difference between high TSP values measured in Denver and those at RMA, is that elevated TSP levels in the Denver metropolitan area were usually associated with high pollution days when industrial and vehicular emissions were trapped under an inversion when winds were light. These conditions prevented mixing and dispersion of the pollutants. In contrast, some RMA high TSP days were associated with strong, gusty winds that lifted disturbed soils in the vicinity of the Basin F remediation activity, or that activated some non-RMA sources during the Phase 3 and 4 periods.

4.1.5 Total Suspended Particulates Sources

The sources of TSP at RMA are numerous and variable by season and meteorological conditions. Factors which influence TSP concentrations include metropolitan Denver traffic as well as industrial and domestic activities which contribute to the brown cloud, meteorological conditions which include wind speed, wind direction, precipitation, inversion conditions, seasonal and climatological variations as well as variable on-site construction, reclamation and remediation activities. Colorado Department of Health statistics indicate that several major stationary particulate sources surrounding RMA emit 25 tons or more per year. A number of these sources are within 2 miles of the Arsenal. The majority of these sources are located to the southwest of RMA (CDH, 1990).

During Basin F remediation, a direct relationship between massive earth moving activities and TSP levels was clear. Mechanical suspension by heavy machinery traffic and soil handling was a major contributing factor, but high, gusty winds also contributed significantly from time to time. When the combined data from IRA-F and CMP are reviewed, seasonal trends become

evident. The highest observed concentrations of TSP occurred in the summer months, and the lowest were observed during the spring wet season. In general, winter and fall exhibited moderate TSP levels. The influence of the Denver metropolitan area on RMA air quality was evident in winter and fall air monitoring data when the southern and western CMP boundary sites reflected the brown cloud conditions by recording the highest observed RMA TSP concentrations. Interior RMA sites, which were closest to on-site disturbed areas and were most susceptible to seasonal winds, tended to show their highest TSP concentrations during the summer.

4.2 RESPIRABLE PARTICULATES

Respirable particulates (PM-10) were generated during dry windy conditions, but to a much lesser extent than TSP. During the IRA-F program, PM-10 samples were collected on a 12-day cycle at FC-1 and FC-3. No PM-10 samples were collected around Basin F during Phase 1 or Phase 2.

4.2.1 Recovery of PM-10 Samples

Percent recoveries of PM-10 samples are provided in Table 4.2-1. Overall PM-10 recovery was 87.5 percent. Power outages during the late spring and summer 1989 were the cause of most lost samples.

4.2.2 Mean PM-10 Concentrations

Table 4.2-2 presents arithmetic mean PM-10 concentrations for Phases 3 and 4. Prior to Phase 3 PM-10 was not sampled in the Basin F vicinity. Concentrations were essentially uniform during both Phase 3 and Phase 4 sampling. The PM-10 sampling sites were located upwind and downwind of the former Basin F relative to the prevailing wind flow. There were no significant differences in results the data, suggesting that the former Basin F was not a predominant source of PM-10 during the post-remediation period.

4.2.3 Maximum PM-10 Concentrations

A summary of 24-hour maximum PM-10 concentrations is given in Table 4.2-3. As in the case of TSP, each site experienced its maximum concentration on September 14, 1990, with levels of

Table 4.2-1 Recovery of IRA-F PM-10 Samples

STATION	NUMBER OF SAMPLES IN PERIOD	NUMBER OF VALID SAMPLES	RECOVERY PERCENT
FC-1	41	36	87.8
FC-3	39	34	87.2
All Stations	80	70	87.5

Table 4.2-2 Arithmetic Mean PM-10 Concentrations ($\mu\text{g}/\text{m}^3$) at IRA-F Sampling Locations

STATION	PHASE 3	PHASE 4
FC-1	23	24
FC-3	22	23

Table 4.2-3 24-Hour Maximum PM-10 Concentrations ($\mu\text{g}/\text{m}^3$) at IRA-F Sampling Locations

STATION	PHASE 3	PHASE 4
FC-1	35	102
FC-3	36	88

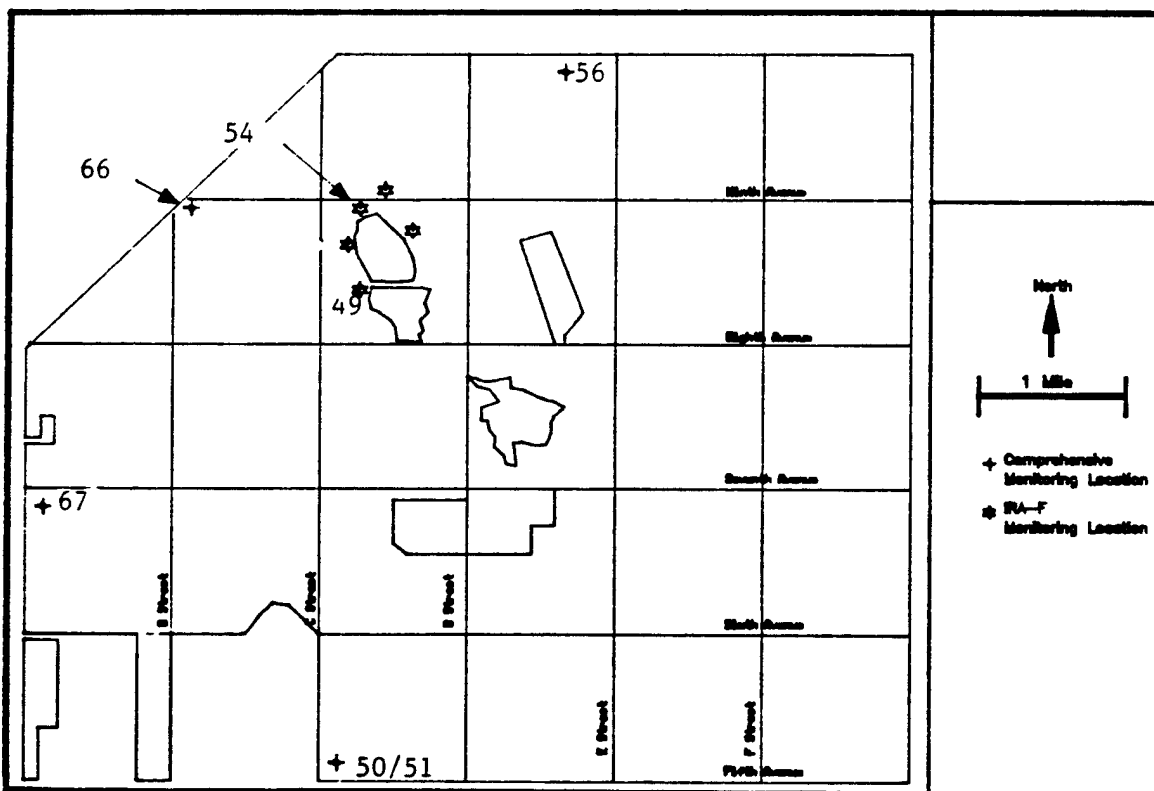
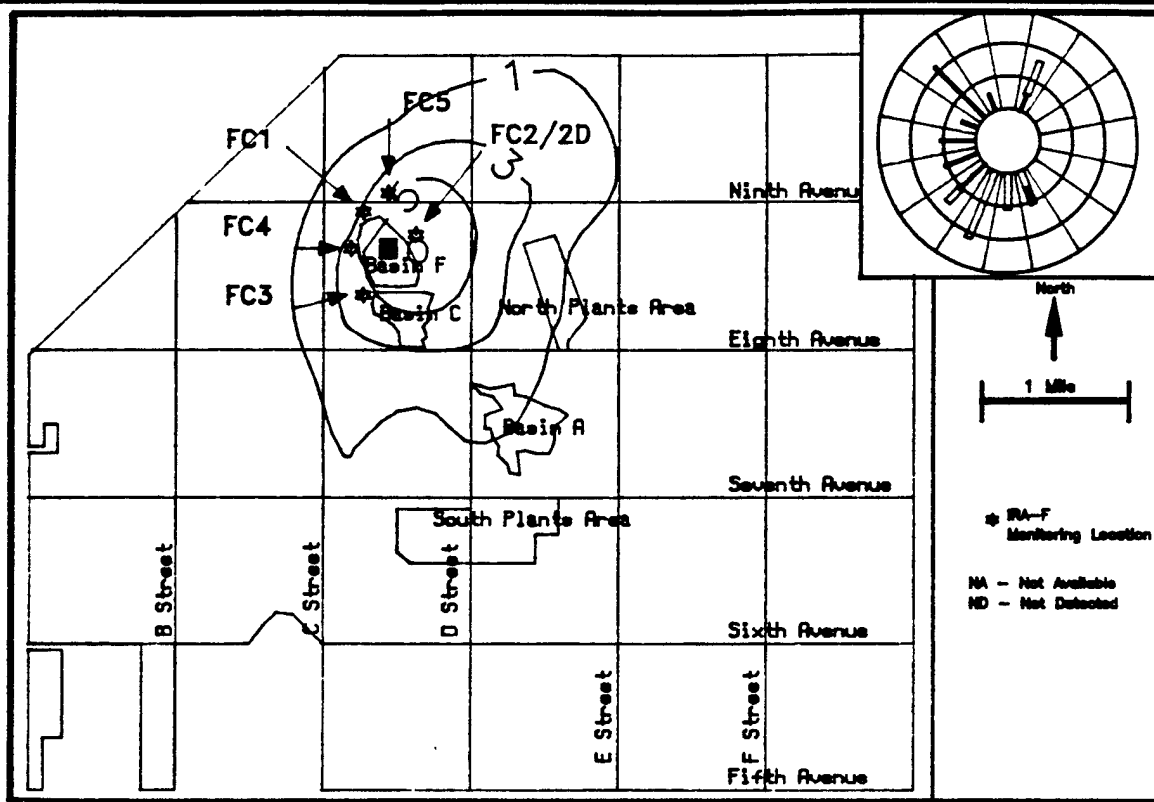
102 $\mu\text{g}/\text{m}^3$ and 88 $\mu\text{g}/\text{m}^3$ at FC-1 and FC-3 respectively. Aside from this day, the next highest maximum was 54 $\mu\text{g}/\text{m}^3$ at site FC-1.

The extreme PM-10 events were selected from the IRA-F monitoring results which showed elevated concentrations for the sample days. Meteorological conditions, such as moderate winds and dry surface conditions were also considered during the selection process. The results were matched with the dispersion patterns of the corresponding 24-hour sampling periods to correlate the actual results with the theoretical dispersion. The highest and second highest concentrations for both PM-10 sampling sites occurred on the same 2 days as were examined for high TSP levels, October 25, 1989, and September 14, 1990. Both days showed correspondingly high PM-10 levels at the CMP monitoring sites as well.

4.2.3.1 PM-10 High Event: October 25, 1989

October 25, 1989, was a typical high particulates day for both TSP and PM-10. Figure 4.2-1 shows the X/Q dispersion pattern, the corresponding wind rose, and the reported IRA-F PM-10 concentrations and pertinent CMP PM-10 data for the day. Winds were moderately gusty from the southwest in the early morning hours, then from the west to northwest until noon. At noon the winds switched back to southwest and exceeded 10 mph for 2 hours before developing a northerly component and dropping to lower speeds. Strong south to southeast winds were present the last 3 hours of the day. As has been typical of high particulates days at RMA, wind speeds during several hours exceeded 10 mph and, notably, the gusty winds were largely from the south to southwest. Ground surface conditions were dry, with the most recent precipitation recorded on October 16, 1990.

The highest level recorded was 54 $\mu\text{g}/\text{m}^3$ at IRA-F site FC-1. On the southwest (upwind) side of the basin, a PM-10 level of 49 $\mu\text{g}/\text{m}^3$ was recorded at FC-3. The majority of the concentrations measured at the CMP sites were comparable to those of the IRA-F sites making the results of the two FC samplers average for the day. As with the TSP samples for the same day, the highest CMP PM-10 concentrations were recorded at AQ1, 67 $\mu\text{g}/\text{m}^3$, and AQ2,



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Figure 4.2-1

X/Q Dispersion Pattern, Wind Rose and PM-10
Concentrations for October 25, 1989

($\mu\text{g}/\text{m}^3$)

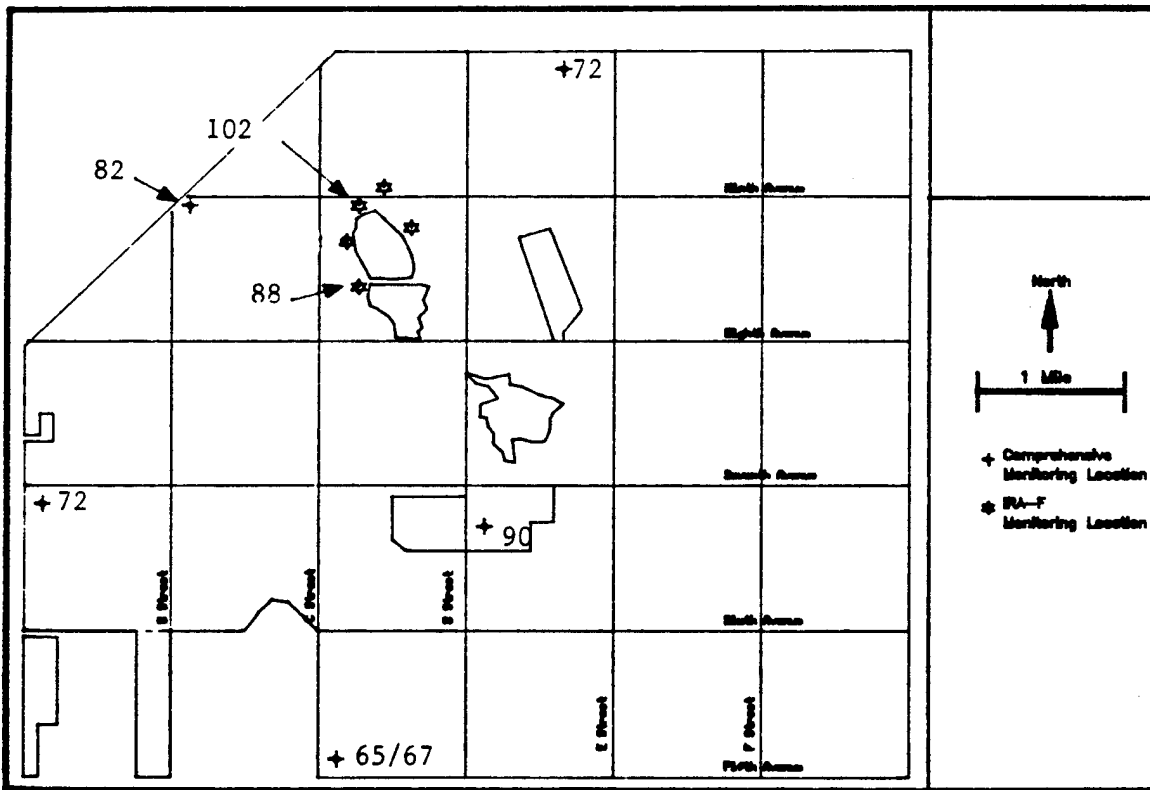
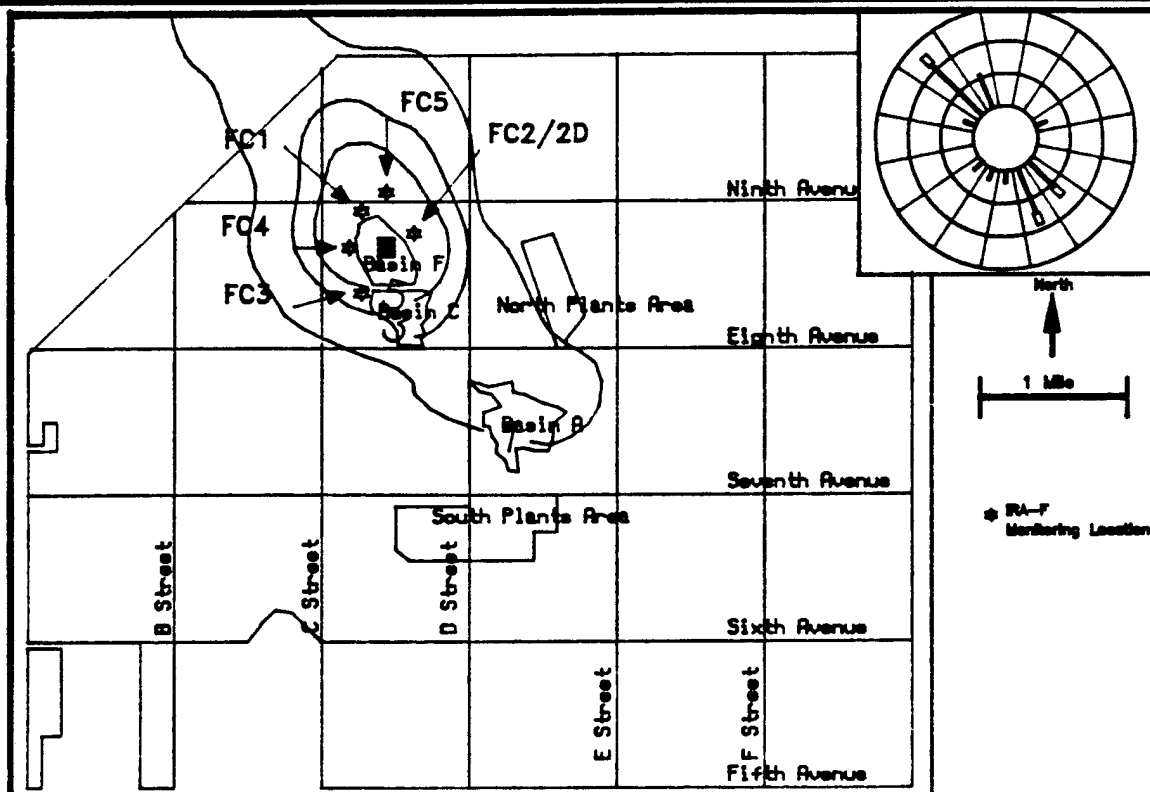
66 $\mu\text{g}/\text{m}^3$. Both these samplers were located at the western boundary of RMA and were upwind of the former Basin F on those days. All CMP and IRA-F PM-10 concentrations for the day were about twice the long-term RMA average.

Review of CDH sampling data confirmed that this day had very high particulate concentrations across the Denver metropolitan area. Photos taken by the CMP during the day revealed the presence of a brown cloud and the resulting reduced visibility (Stollar, 1991). This brown cloud traversed RMA from south-to-north, then north-to-south as the day progressed, in the typical diurnal drainage pattern commonly experienced in the Denver metropolitan area. While the sampling site immediately downwind of the former Basin F during the gusty periods recorded slightly higher particulates than some other sites, the RMA boundary sites upwind of the basin recorded even higher concentrations. It is interesting that the northern boundary CMP site, AQ3, also recorded a higher PM-10 concentration (56 $\mu\text{g}/\text{m}^3$) than FC-1, which was much closer to the former Basin F.

Because the highest PM-10 levels were recorded at sites that at no time were downwind of the former Basin F, it is apparent that the high particulates impacts were in fact from a source which was off RMA. There was no evidence of an impact from windblown soil off the former Basin F. The remediation effort by this time had stabilized the Basin F soils. The results from this event clearly indicate that non-RMA sources are responsible for the extreme maximum PM-10 levels.

4.2.3.2 PM-10 High Event: September 14, 1990

September 14, 1990, produced unusually high particulates throughout the Denver metropolitan area, RMA, and a good portion of eastern Colorado. Figure 4.2-2 shows the X/Q dispersion pattern, the corresponding wind rose and the reported IRA-F PM-10 concentrations along with applicable CMP data for the day. Several separate atmospheric inversion layers at various altitudes, combined with light winds, caused limited vertical mixing, thus creating the conditions which encourage development of a high pollution day. Until late morning, winds were from the south-southeast, changing to north-northwesterly around 10:00 MST, then returning to the south-



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Figure 4.2-2

X/Q Dispersion Pattern, Wind Rose and PM-10
Concentrations for September 14, 1990

($\mu\text{g}/\text{m}^3$)

southeasterly in the late evening. Wind speeds remained low the entire day. The ground surface was dry, with the most recent precipitation having been a trace 9 days before. There was a heavy haze throughout the area, which completely obscured the view of the mountains. The brown cloud was very evident from south to north along the foothills.

Sampling site FC-1, which was downwind from the former Basin F for half the day, and upwind the other half, recorded the highest PM-10 concentration of $102 \mu\text{g}/\text{m}^3$, a level that was comparable to CMP site AQ10 which recorded a concentration of $90 \mu\text{g}/\text{m}^3$. At FC-3, on the southwest side of the former Basin F, a concentration of $88 \mu\text{g}/\text{m}^3$ was recorded. All PM-10 levels for RMA sample sites were three to four times higher than the RMA average.

In light of the TSP and PM-10 concentrations recorded for the Denver metropolitan area on this day, it is evident that concentrations recorded at RMA sites reflected the overall area-wide conditions. The typical diurnal drainage wind flow pattern which manifested itself during the day would have pushed the brown cloud across RMA twice during the day, once from the southeast, and the second time from the northwest. This particular extreme event day was discussed in detail in the Air Quality Data Assessment Report for the CMP (Stollar, 1991).

4.2.4 Comparison With Other Local PM-10 Data

The CMP routinely collected PM-10 data at five sites (four on the RMA boundary and one at the center of RMA) both prior to and during the IRA-F program. A comparison with PM-10 data collected under the CMP reveals that FY90 values for both annual arithmetic mean and 24-hour maximum were lower than in FY89. As with IRA-F data, the highest PM-10 values occurred on September 14, 1990, which confirms the validity of the IRA-F samples of this date. In general, the highest levels of PM-10 were collected at the boundary sites, and the highest overall concentrations were encountered in the fall through winter periods. The highest geometric mean monthly concentration was reported in October 1989 when $40 \mu\text{g}/\text{m}^3$ was measured at AQ2 and $39 \mu\text{g}/\text{m}^3$ was measured at AQ1. Both sites are near the western boundary of RMA, and normally reflect the impact of non-RMA sources.

As was found with TSP, PM-10 concentrations recorded at RMA were lower than those recorded at CDH stations in the Denver metropolitan area. Using CMP data (to supplement the IRA-F data), along with CDH data, it becomes apparent that there was an influx of PM-10 into RMA from the Denver metropolitan area. Data from CDH and CMP generally indicate that during Phase 1, PM-10 levels were fairly uniform throughout the Denver metropolitan area and at RMA. The highest average concentration was $40 \mu\text{g}/\text{m}^3$ reported in Adams City (downwind from the metropolitan area). The Phase 2 time period produced comparable high results between downtown Denver (upwind of RMA) and Adams City (downwind from RMA). Data collected on RMA reflected the levels in CDH data, with the highest concentrations at the CMP sites on the western and southern boundaries. The record of high PM-10 concentrations recorded at RMA parallels data collected for the Denver metropolitan area by CDH. A detailed discussion comparing CMP data and CDH data was presented in the Air Quality Data Assessment Report for the CMP (Stollar, 1991).

Through the remainder of the IRA-F period, variability in PM-10 concentrations largely reflected the variability in Denver metropolitan area results. The highest recorded levels on RMA remained at the western and southern boundary sites. Mobile sampler AQ10B recorded higher levels while it was located near the South Plants subdrain construction activity. Excavation and emissions from heavy equipment would be expected to raise PM-10 in the immediate vicinity, and the sampler was positioned approximately 100 yards downwind from the activity center, reflecting the nearby impact of that source.

4.2.5 PM-10 Sources

As in the case of TSP, there were two principal potential sources of PM-10 that impacted RMA and the surrounding area. The major source was the influx of emissions from the Denver metropolitan area. With consistently high PM-10 results at the western and southern boundary CMP sites, it is apparent the major impact originates from the southwest. To a lesser extent, RMA remedial operations potentially emitted PM-10 in the form of wind-suspended particulates that had been loosened during construction, and particulate emissions from the heavy equipment

used to perform the work. This source is difficult to confirm with the available results. During the time remediation activity was ongoing, data were collected at more distant sites, and did not indicate a detectable increase in average PM-10 levels associated with remedial activities. This may be the result of the lack of PM-10 monitoring stations immediately adjacent to the remedial activities. It appears, therefore, that any remediation-generated PM-10 emissions were localized, and decreased significantly with distance from the activity, producing negligible off-post impacts.

4.3 METALS

The ICAP metals (cadmium, chromium, copper, lead and zinc) were analyzed from all the valid TSP filters collected under IRA-F. Sampling was conducted at all sites on a 12-day frequency and included the analysis of metals collected at BF-5, BF-7 and RIFS1 during May and June 1989.

4.3.1 Recovery of Metals Samples

Table 4.3-1 presents percent recoveries of metals samples during the IRA-F program. All samples collected at sites BF-5, BF-7 and RIFS1 during their brief sampling period were recovered. All sites had recoveries above 75 percent, with the exception of FC-1 for which the recovery was 74 percent. Some samples were lost due to power failures at this site during the late spring and summer of 1989. The overall recovery of ICAP metals for the project was 85.6 percent. Metals recoveries for sites FC-1 through FC-5 were less than the corresponding recoveries for TSP because filters with high background levels of zinc were used from August 14, 1989, to September 19, 1989, and on October 13, 1989. These contaminants invalidated the metals results but did not invalidate the corresponding TSP gravimetric analyses used to determine TSP concentration. Phase 4 recoveries, representing a complete year of data, showed substantially higher recoveries.

4.3.2 Mean Metals Concentrations

A summary of the arithmetic mean concentrations of metals is presented in Table 4.3-2. Some metals showed a decrease in concentration with time, while others were relatively unaffected by

Table 4.3-1 Recovery of IRA-F Metals Samples

STATION	NUMBER OF SAMPLES IN PERIOD	NUMBER OF VALID SAMPLES	RECOVERY PERCENT
FC-1	43	32	74.4
FC-2	43	38	88.4
FC-2D	43	38	88.4
FC-3	43	37	86
FC-4	43	37	86
FC-5	40	34	85
BF-5	5	5	100
BF-7	5	5	100
RIFS1	5	5	100
All Stations	270	231	85.6

Table 4.3-2 Arithmetic Mean Metals Concentrations ($\mu\text{g}/\text{m}^3$) at Basin F/IRA-F Sampling Locations

Site	Cadmium	Chromium	Copper	Lead	Zinc
Phase 1 (3/22/88 - 12/12/88)					
BF-1	0.0006	0.0128	0.1163	0.0148	0.0688
BF-2	0.0008	0.0101	0.1516	0.0175	0.0727
BF-2C	0.0005	0.0126	0.1539	0.0172	0.0951
BF-3	0.0005	0.0176	0.0944	0.0138	0.0776
BF-4	0.0006	0.0200	0.1258	0.0160	0.0779
BF-5	0.0006	0.0026	0.0712	0.0144	0.0508
BF-6	0.0005	0.0032	0.0746	0.0146	0.0472
BF-7	0.0006	0.0023	0.0791	0.0140	0.0493
Phase 2 - Stage 1 (12/13/88 - 2/15/89)					
BF-1	0.0009	0.0036	0.0569	0.0200	0.2243
BF-2	0.0006	0.0037	0.0646	0.0220	0.0931
BF-2C	0.0006	0.0045	0.0687	0.0215	0.1476
BF-3	0.0007	0.0026	0.0566	0.0181	0.1952
BF-4	0.0007	0.0028	0.0578	0.0202	0.1494
BF-5	0.0006	0.0031	0.0522	0.0159	0.3260
BF-6	0.0006	0.0027	0.0679	0.0167	0.0524
BF-7	0.0005	0.0033	0.0684	0.0173	0.1915
RIFS1	0.0016	ND*	0.0762	0.0397	0.0539
RIFS1D	0.0018	ND	0.0851	0.0405	0.0509
RIFS2	0.0007	ND	0.0783	0.0248	0.0337
Phase 2 - Stage 2 (2/16/89 - 5/5/89)					
BF-1	0.0008	0.0026	0.0429	0.0134	0.1052
BF-2	0.0006	0.0031	0.0528	0.0148	0.0716
BF-2C	0.0005	0.0034	0.0817	0.0152	0.0730
BF-3	0.0006	0.0025	0.0546	0.0137	0.1203
BF-4	0.0006	0.0029	0.0533	0.0135	0.0430
BF-5	0.0023	0.0022	0.0377	0.0134	0.0832
BF-6	0.0004	0.0032	0.0445	0.0145	0.0403
BF-7	0.0006	0.0024	0.0701	0.0133	0.0814
RIFS1	0.0008	0.0031	0.0999	0.0232	0.0413
RIFS1D	0.0012	ND	0.1072	0.0231	0.1105
RIFS2	0.0008	ND	0.0899	0.0218	0.0363
Phase 3 (5/6/89 - 9/30/89)					
FC-1	0.0013	ND	0.1434	0.0255	0.0217
FC-2	0.0008	ND	0.0961	0.0152	0.0182
FC-2D	0.0007	ND	0.1366	0.0140	0.0195
BF-3/FC-3	0.0007	ND	0.1081	0.0147	0.0204
BF-4/FC-4	0.0007	ND	0.1095	0.0148	0.0196
BF-5	0.0006	ND	0.1148	0.0176	0.0250
FC-5	0.0003	ND	0.1516	0.0092	0.0257
BF-7	0.0006	ND	0.1466	0.0164	0.0197
RIFS1	0.0007	ND	0.1362	0.0183	0.0303
Phase 4 (10/1/89 - 9/30/90)					
FC-1	0.0005	0.0027	0.0994	0.0100	0.0216
FC-2	0.0004	0.0026	0.0903	0.0099	0.0223
FC-2D	0.0004	ND	0.0930	0.0097	0.0212
FC-3	0.0004	ND	0.0494	0.0102	0.0207
FC-4	0.0004	ND	0.0741	0.0102	0.0236
FC-5	0.0003	0.0030	0.0710	0.0108	0.0252

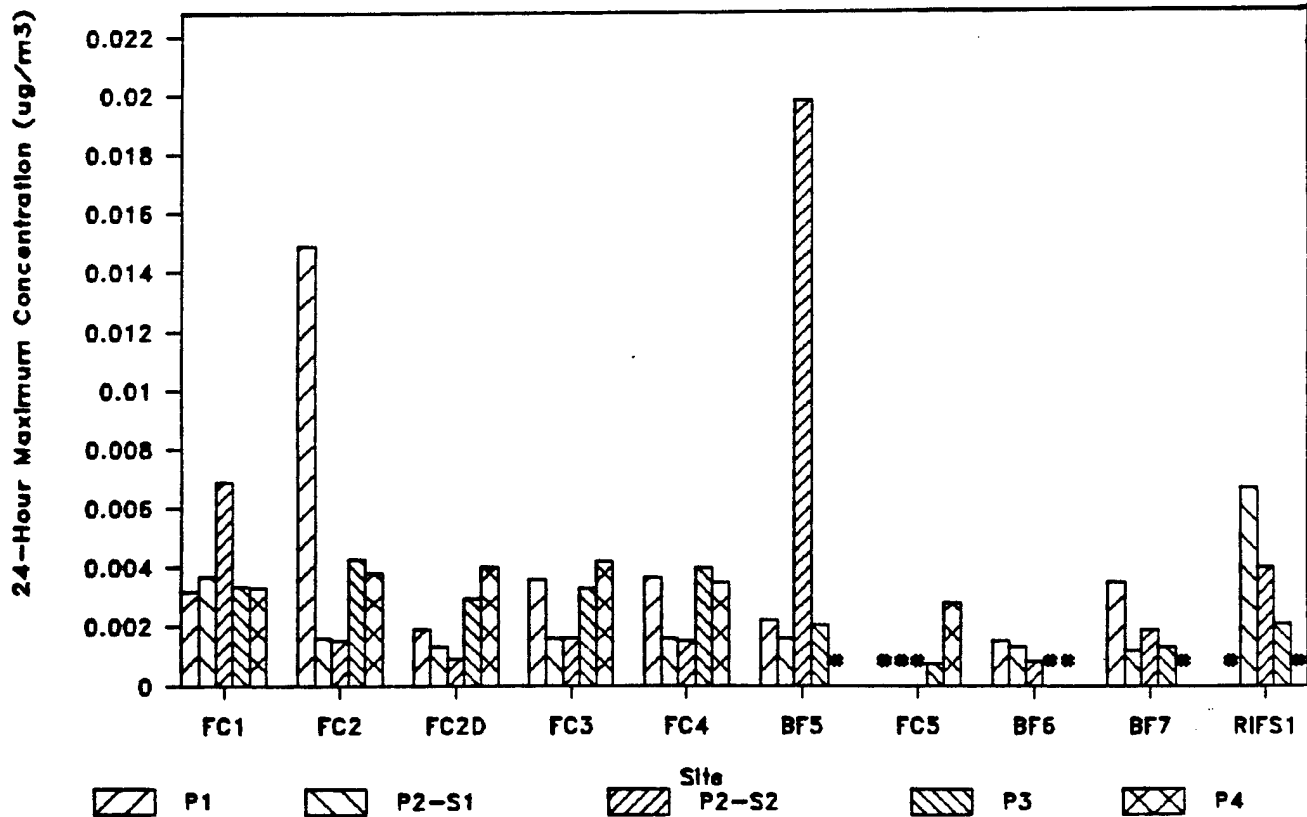
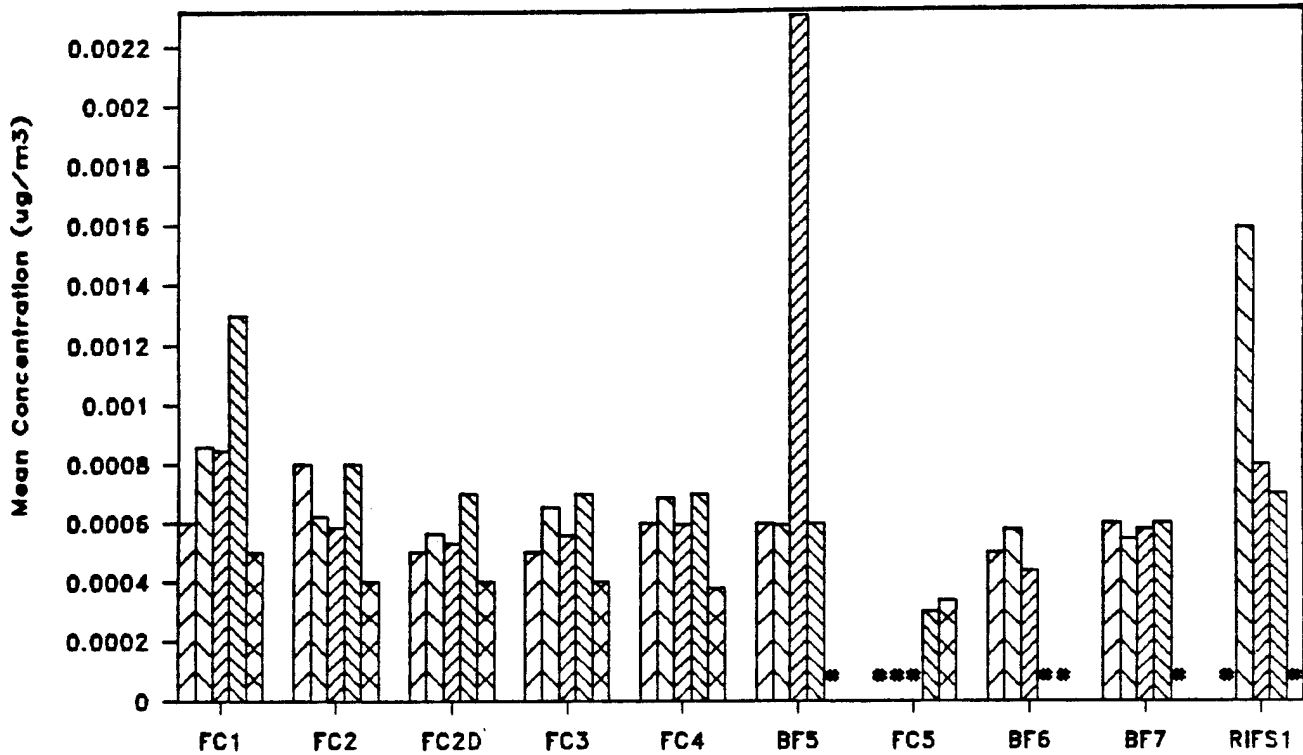
* ND = Not Detected

the remedial activity. The numerical values are provided to document the actual concentrations; however, an interpretation of these data can best be made through the graphical presentations in Figures 4.3-1 through 4.3-5, which illustrate the mean and maximum trends from Phase 1 through Phase 4. The mean concentration for each metal at each site and for each phase is shown. Note that the vertical scale differs among the analytes. Cadmium displayed generally constant concentrations in all phases at all sites, but the lowest concentrations were seen in Phase 4 at sites on the Basin F perimeter. An anomalously high concentration of $0.0023 \mu\text{g}/\text{m}^3$ occurred at BF-5, during Phase 2, Stage 2. The highest levels of chromium were detected during Phase 1, with maximum values at the Basin F perimeter sites, but during Phases 3 and 4 it was detected on only 1 day, at three sites. Copper did not display a consistent pattern. The highest mean concentration of copper occurred during Phases 1 and 3, and relatively lower levels were noted in Phases 2 and 4. Lead showed largely uniform concentrations during the first three phases, but was a slightly reduced at all sites in Phase 4. Zinc levels exhibited a substantial drop from Phase 2 to Phase 3 and remained fairly steady from Phase 3 to Phase 4.

4.3.3 Maximum Metals Concentrations

The 24-hour maximum concentrations for each metal are presented in Table 4.3-3. Maximum levels show trends similar to those of the mean concentrations. Chromium and zinc were highest during Phases 1 and 2, with significantly lower maxima thereafter. Copper showed its highest maximum values during Phase 1, but maximum levels were somewhat uniform during the other phases. Maxima for both lead and cadmium were fairly constant throughout all phases, given what appears to be two anomalous spikes in maximum cadmium concentrations.

The extreme events discussed in the following subsections were selected from IRA-F sample days having the highest metals concentrations. The two days selected for discussion were November 18, 1989, and September 14, 1990 (a day already discussed under both TSP and PM-10). Selection also took into account meteorological conditions, such as moderate winds and dry surface conditions. The results were matched with the dispersion patterns of the corresponding 24-hour sampling periods to correlate the actual results with the theoretical



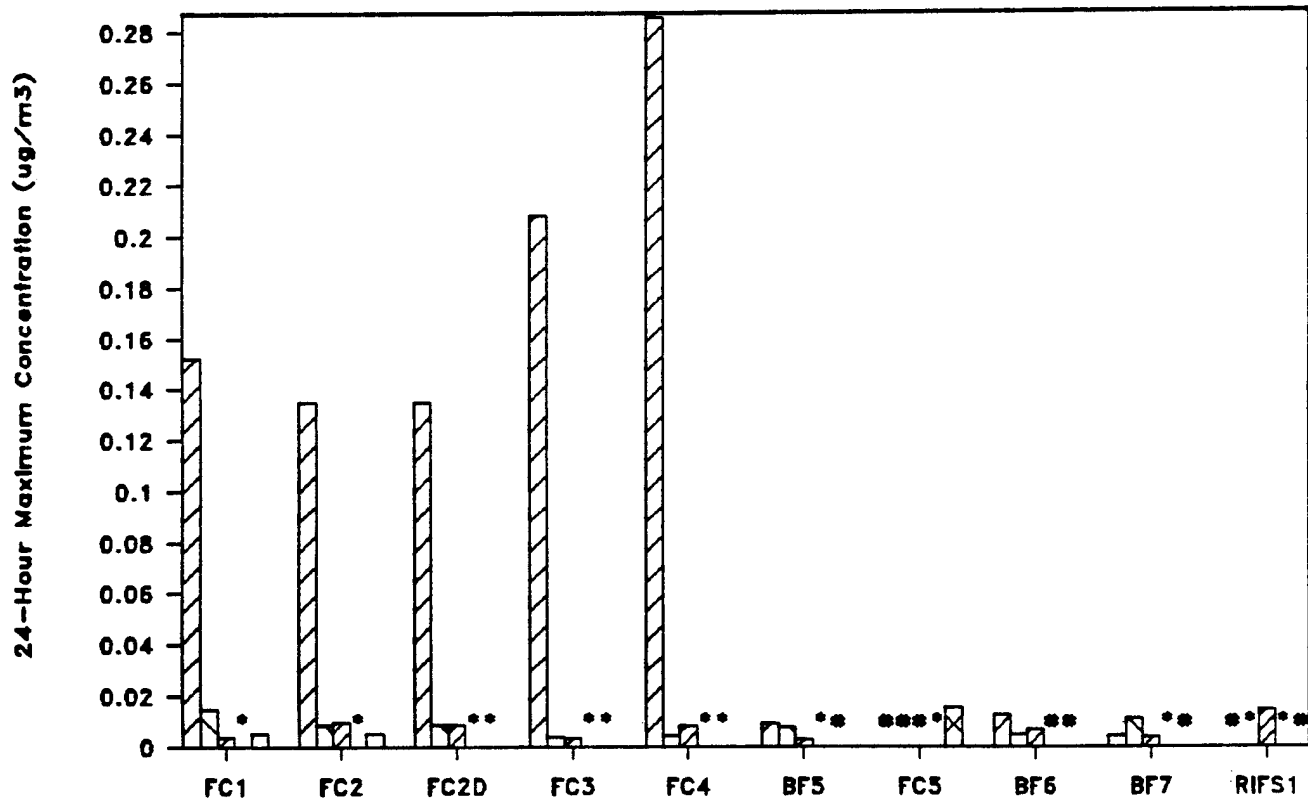
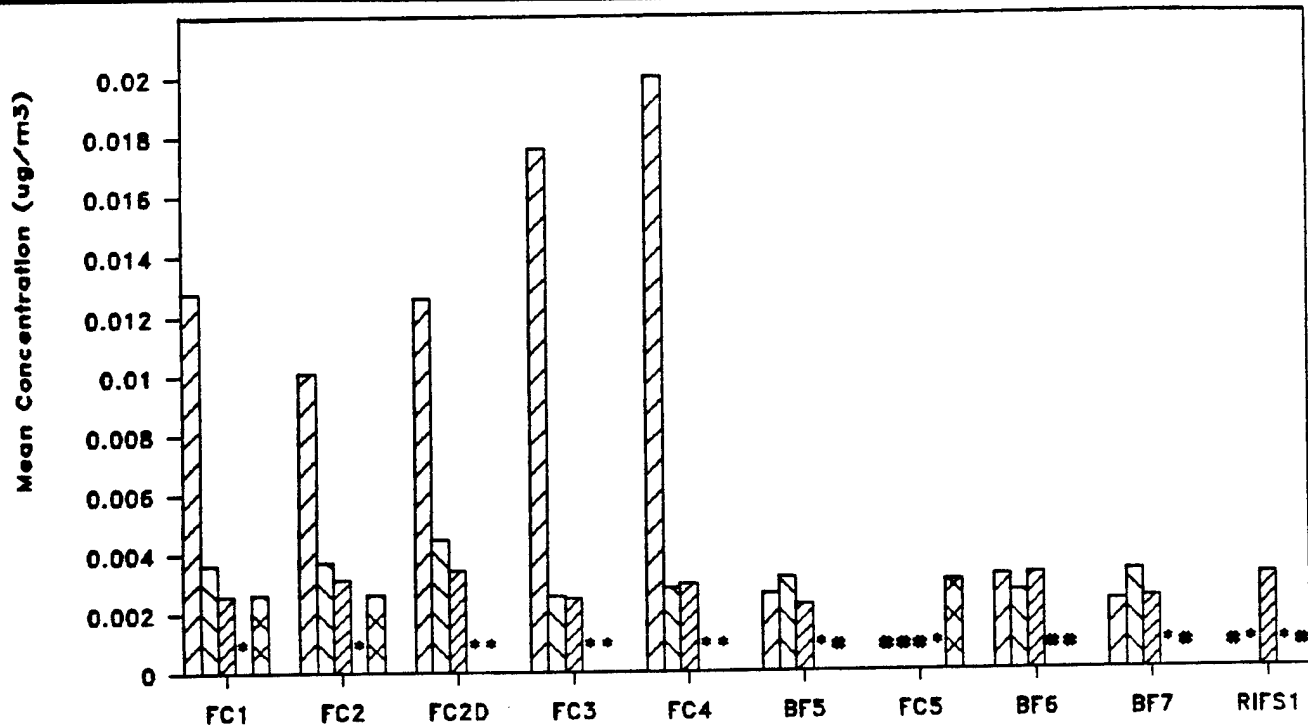
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Figure 4.3-1

Mean and Maximum Concentrations for Cadmium
by Site, by Phase

Not an Analyte This Phase



P1
 P2-S1
 P2-S2
 P3
 P4

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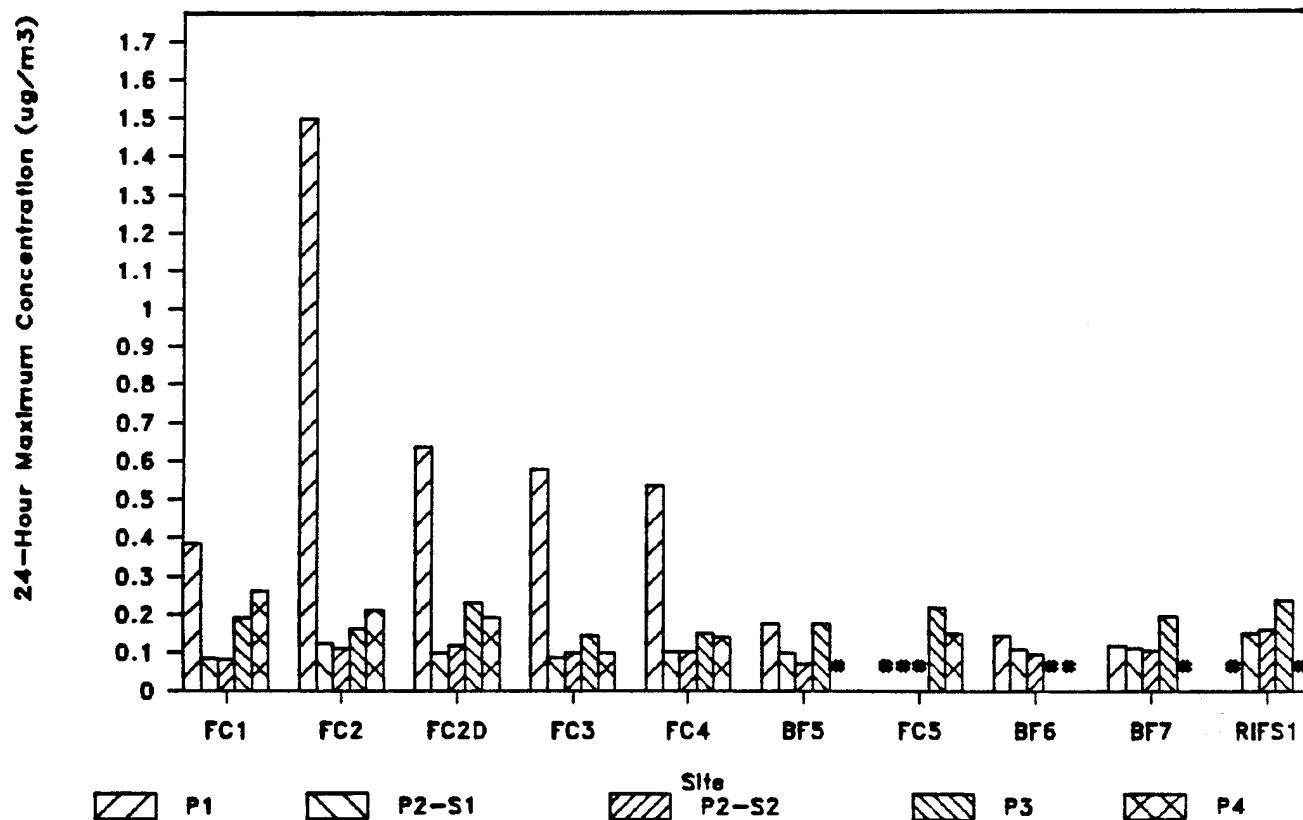
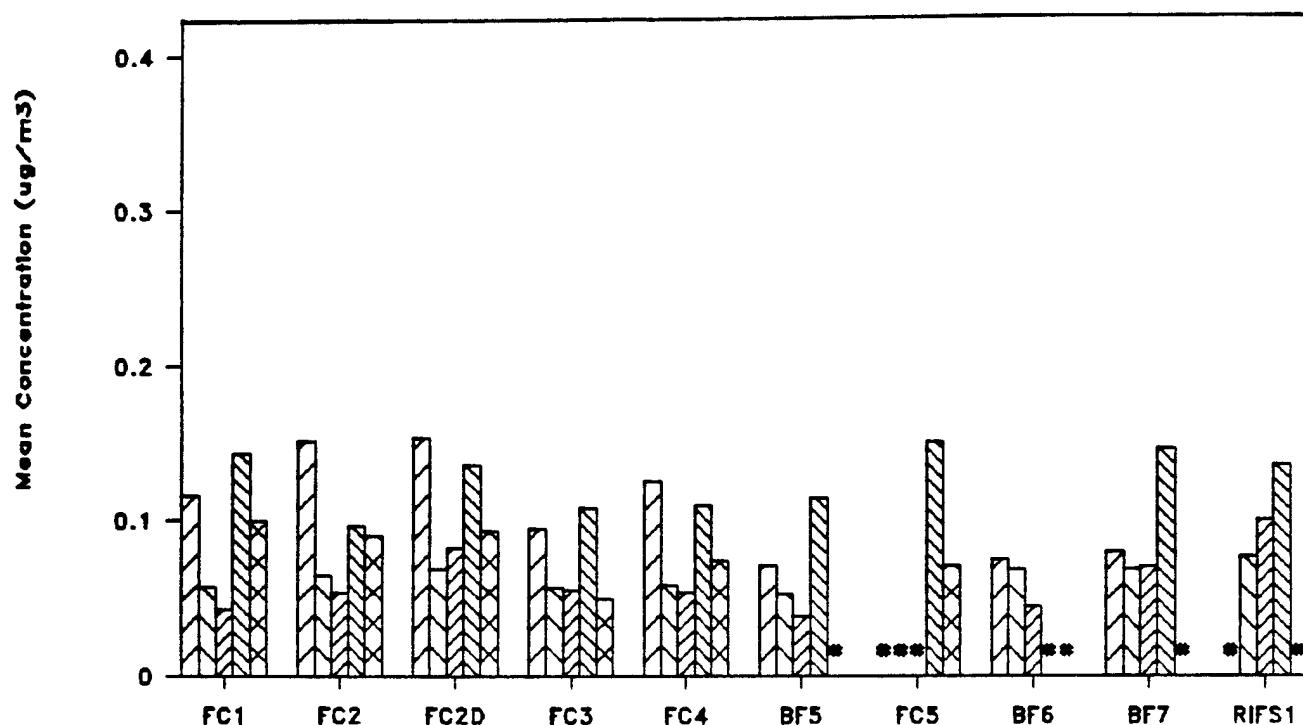
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Figure 4.3-2

Mean and Maximum Concentrations for Chromium
by Site, by Phase

*Not Detected

Not an Analyte This Phase



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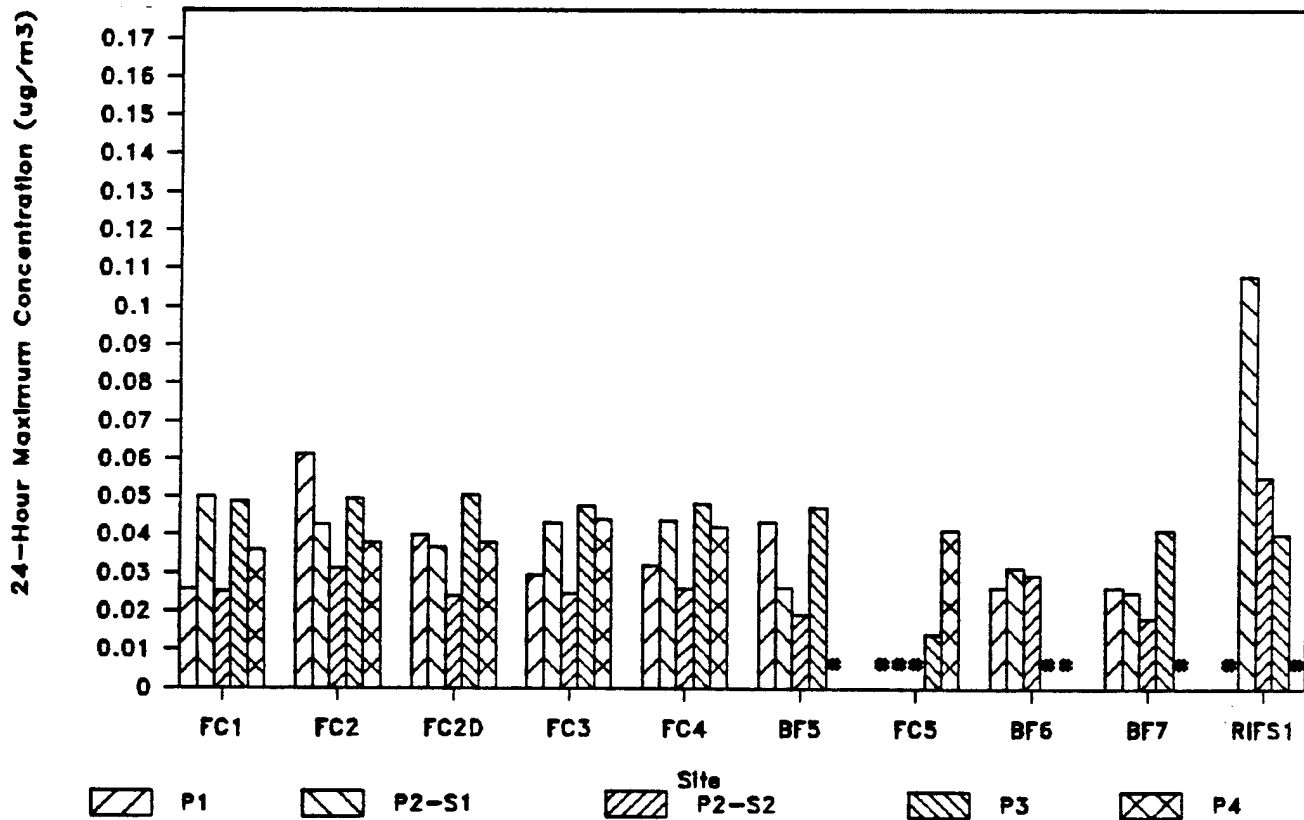
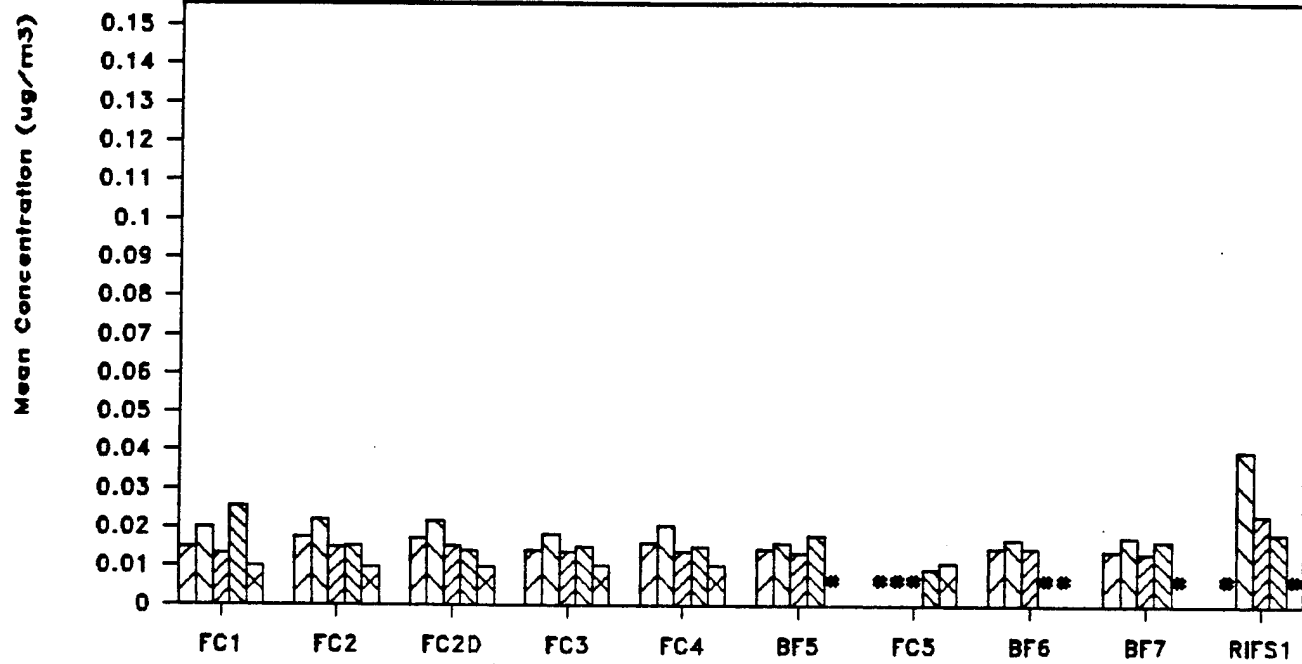
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Figure 4.3-3

Mean and Maximum Concentrations for Copper
by Site, by Phase

Not an Analyte This Phase



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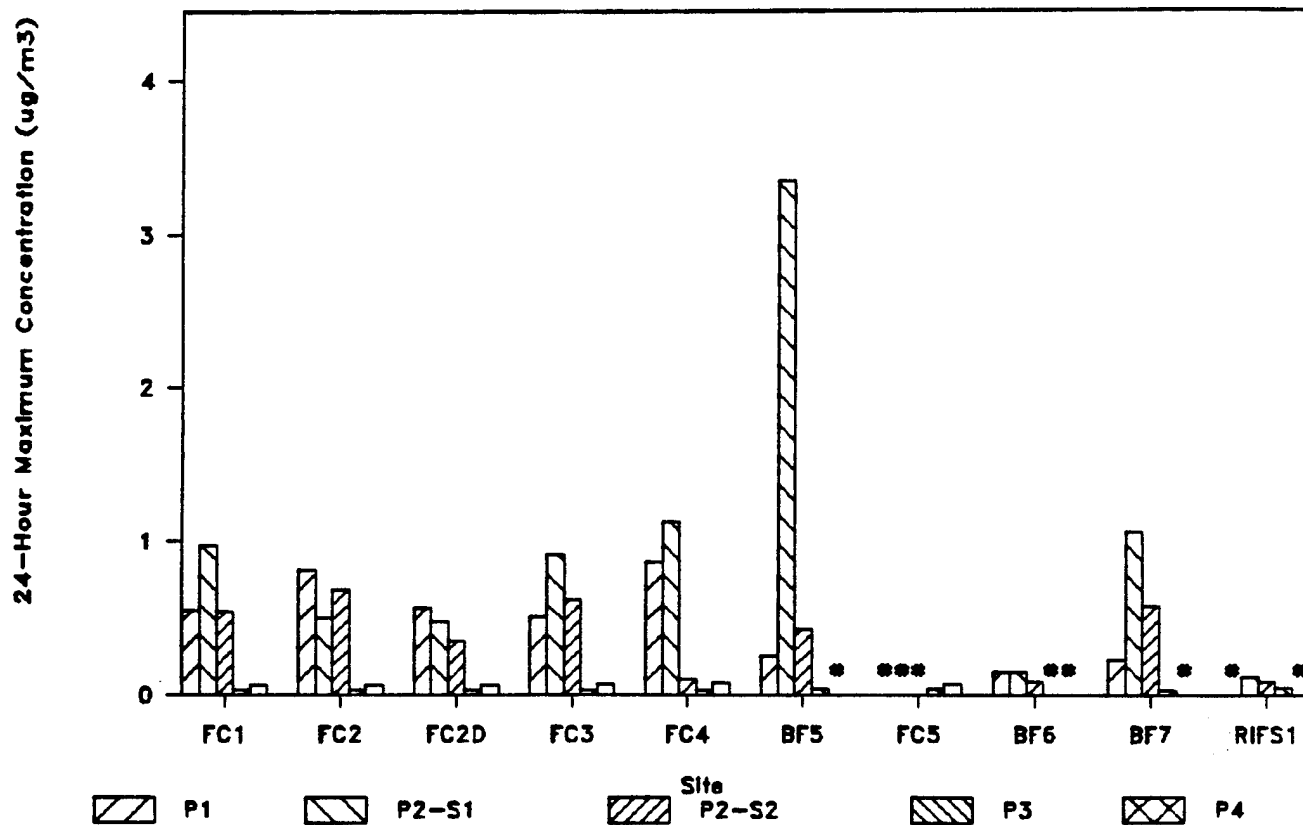
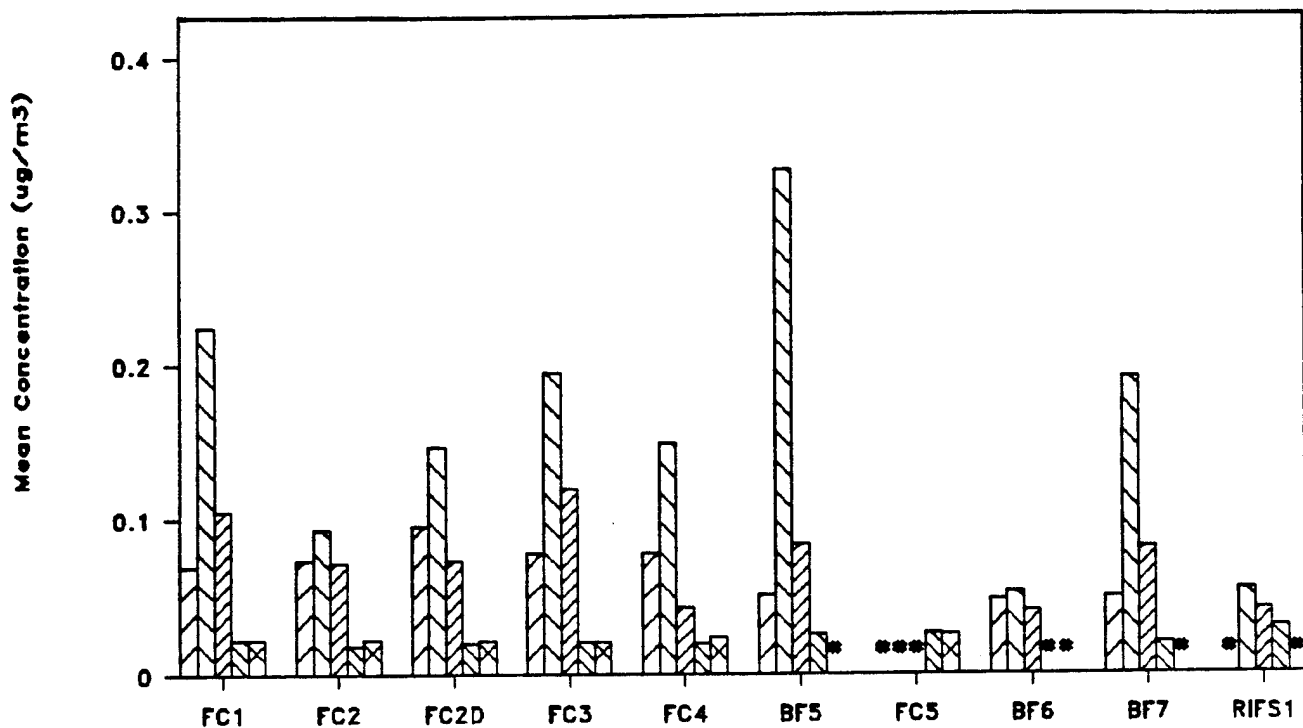
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Figure 4.3-4

Mean and Maximum Concentrations for Lead
by Site, by Phase

* Not an Analyte This Phase



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Figure 4.3-5

Mean and Maximum Concentrations for Zinc
by Site, by Phase

Not an Analyte This Phase

Table 4.3-3 24-Hour Maximum Metals Concentrations ($\mu\text{g}/\text{m}^3$) at Basin F/IRA-F Sampling Locations

Site	Cadmium	Chromium	Copper	Lead	Zinc
Phase 1 (3/22/88 - 12/12/88)					
BF-1	0.0032	0.1520	0.3851	0.0258	0.5471
BF-2	0.0149	0.1350	1.4980	0.0614	0.8106
BF-2C	0.0019	0.1350	0.6349	0.0397	0.5623
BF-3	0.0036	0.2083	0.5760	0.0292	0.5054
BF-4	0.0037	0.2858	0.5349	0.0317	0.8651
BF-5	0.0022	0.0087	0.1758	0.0434	0.2557
BF-6	0.0015	0.0123	0.1413	0.0260	0.1449
BF-7	0.0035	0.0038	0.1174	0.0261	0.2284
Phase 2 - Stage 1 (12/13/88 - 2/15/89)					
BF-1	0.0037	0.0149	0.0839	0.0499	0.9703
BF-2	0.0016	0.0083	0.1226	0.0428	0.4959
BF-2C	0.0013	0.0082	0.0983	0.0366	0.4762
BF-3	0.0016	0.0037	0.0858	0.0430	0.9151
BF-4	0.0016	0.0038	0.1004	0.0436	1.1316
BF-5	0.0016	0.0075	0.0975	0.0260	3.3576
BF-6	0.0013	0.0044	0.1065	0.0312	0.1476
BF-7	0.0012	0.0110	0.1116	0.0247	1.0643
RIFS1	0.0067	ND*	0.1490	0.1080	0.1110
RIFS1D	0.0065	ND	0.1570	0.0674	0.0655
RIFS2	0.0032	ND	0.1680	0.0779	0.0676
Phase 2 - Stage 2 (2/16/89 - 5/5/89)					
BF-1	0.0069	0.0037	0.0804	0.0249	0.5420
BF-2	0.0015	0.0093	0.1112	0.0311	0.6865
BF-2C	0.0009	0.0082	0.1178	0.0239	0.3462
BF-3	0.0016	0.0032	0.0983	0.0244	0.6185
BF-4	0.0015	0.0080	0.1025	0.0257	0.1040
BF-5	0.0199	0.0029	0.0694	0.0191	0.4289
BF-6	0.0008	0.0064	0.0936	0.0292	0.0819
BF-7	0.0019	0.0035	0.1039	0.0182	0.5766
RIFS1	0.0040	0.0141	0.1600	0.0553	0.0854
RIFS1D	0.0042	ND	0.1360	0.0381	0.3330
RIFS2	0.0021	ND	0.1310	0.0385	0.0501
Phase 3 (5/6/89 - 9/30/89)					
FC-1	0.0033	ND	0.1910	0.0489	0.0272
FC-2	0.0043	ND	0.1610	0.0493	0.0268
FC-2D	0.0029	ND	0.2290	0.0502	0.0280
BF-3/FC-3	0.0033	ND	0.1420	0.0475	0.0280
BF-4/FC-4	0.0040	ND	0.1490	0.0482	0.0296
BF-5	0.0021	ND	0.1750	0.0471	0.0393
FC-5	0.0007	ND	0.2160	0.0141	0.0350
BF-7	0.0013	ND	0.1940	0.0411	0.0285
RIFS1	0.0021	ND	0.2360	0.0401	0.0465
Phase 4 (10/1/89 - 9/30/90)					
FC-1	0.0033	0.0052	0.2600	0.0360	0.0600
FC-2	0.0038	0.0051	0.2100	0.0380	0.0600
FC-2D	0.0040	ND	0.1900	0.0380	0.0610
FC-3	0.0042	ND	0.0980	0.0440	0.0670
FC-4	0.0035	ND	0.1400	0.0420	0.0730
FC-5	0.0028	0.0150	0.1500	0.0410	0.0710

* ND = Not Detected 4.3.3.1 Extreme Metals Events

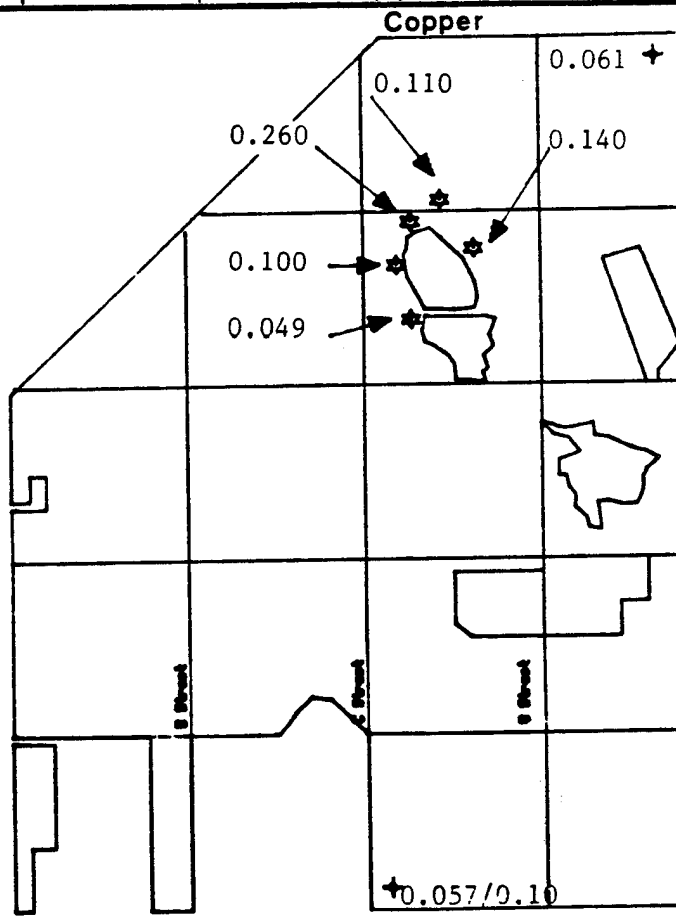
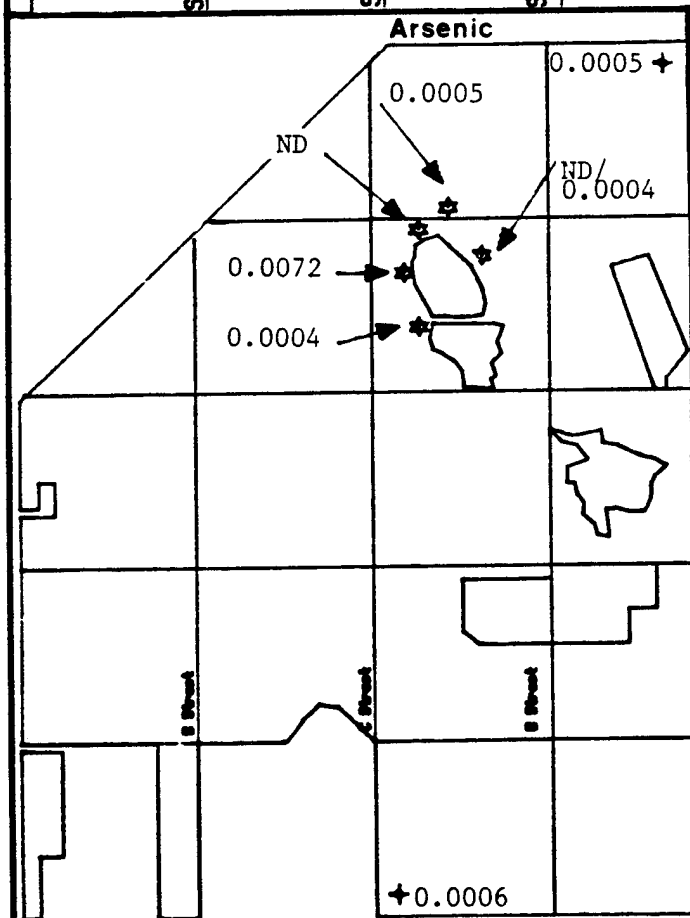
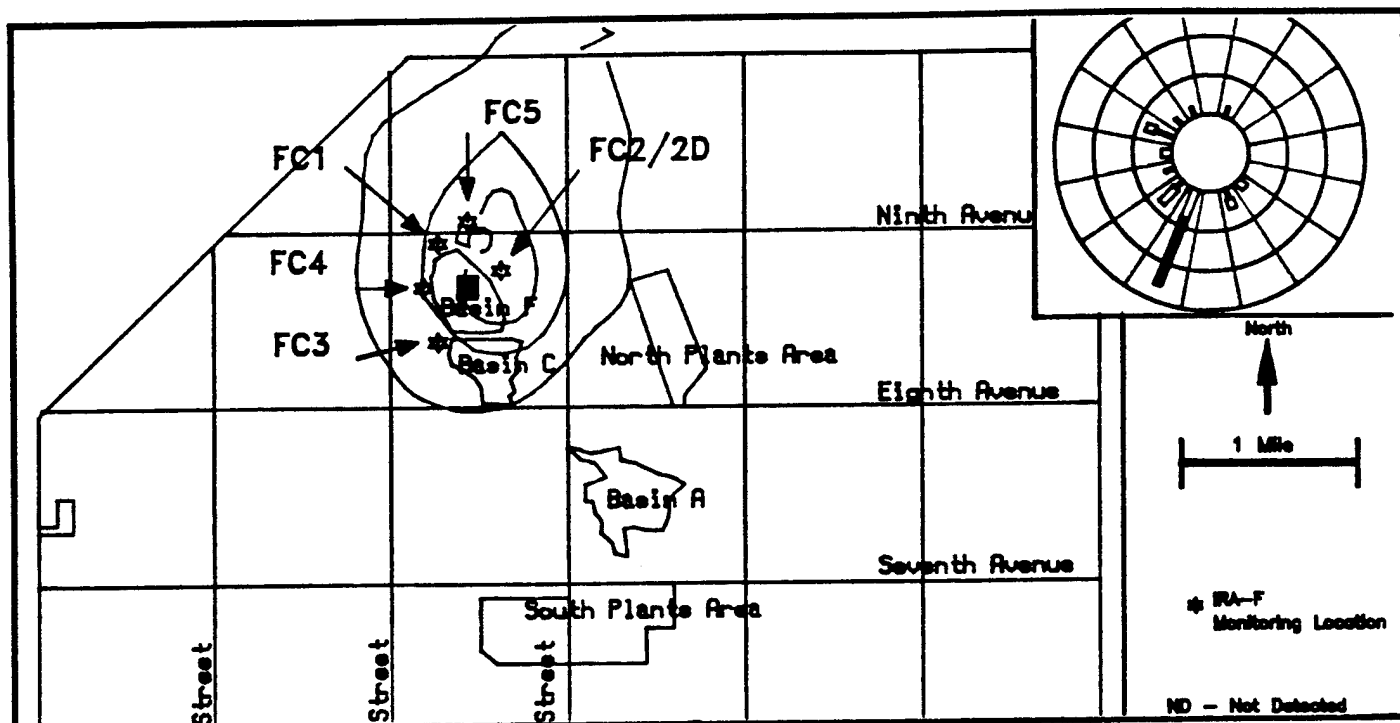
dispersion. The arsenic results are discussed in Section 4.4, but the results from the extreme event days are presented here for comparison.

4.3.3.1 Metals High Event: November 18, 1989

November 18, 1989, was a day with high TSP and PM-10 levels; metals concentrations (including arsenic) were correspondingly high. Figures 4.3-6a and 4.3-6b show the X/Q dispersion pattern, the corresponding wind rose, and the reported IRA-F metals concentrations for this day. Winds were in excess of 10 mph for 11 hours during the day, and 13 mph or greater for 9 of those hours (1 hour averaged 16 mph). Measured particulates at RMA under such wind speeds are nearly always above average. Winds were from the south-southwest, switching to the northwest for several hours at midday, then back toward the south. The highest wind speeds accompanied the southwesterly winds. The ground surface was dry, since the most recent precipitation was small amount at the end of October.

Most of the metals concentrations measured at the IRA-F sites were surprisingly uniform from site to site. The greatest variation in values was for copper, with a concentration of $0.2600 \mu\text{g}/\text{m}^3$ at FC-1 versus the concentration of $0.0490 \mu\text{g}/\text{m}^3$ at FC-3. The highest arsenic concentration was measured at upwind site FC-4 ($0.0072 \mu\text{g}/\text{m}^3$), and the lowest at the lower certified reporting limit (LCRL) of $0.0004 \mu\text{g}/\text{m}^3$ at FC-2D (downwind) and FC-3 (downwind). The CMP sites AQ3, upwind of the former Basin F, and AQ5, the southern boundary site upwind of the former Basin F both had detections of arsenic as well. Otherwise, for other metals, there was no significant difference in values from the upwind side to the downwind side of the former Basin F. The highest zinc concentrations, $0.0350 \mu\text{g}/\text{m}^3$ and lead, $0.0220 \mu\text{g}/\text{m}^3$, were both recorded at AQ5.

Because the highest levels of lead and zinc were measured upwind at the southern boundary station, and the other metals were fairly uniform in concentrations among the sampling sites, it appears that the former Basin F was a negligible source of metals. The source of arsenic is impossible to determine because both the upwind and downwind boundary sites recorded similar



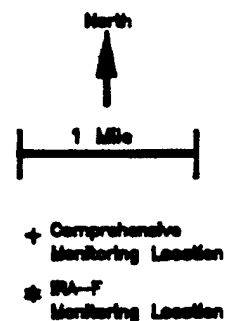
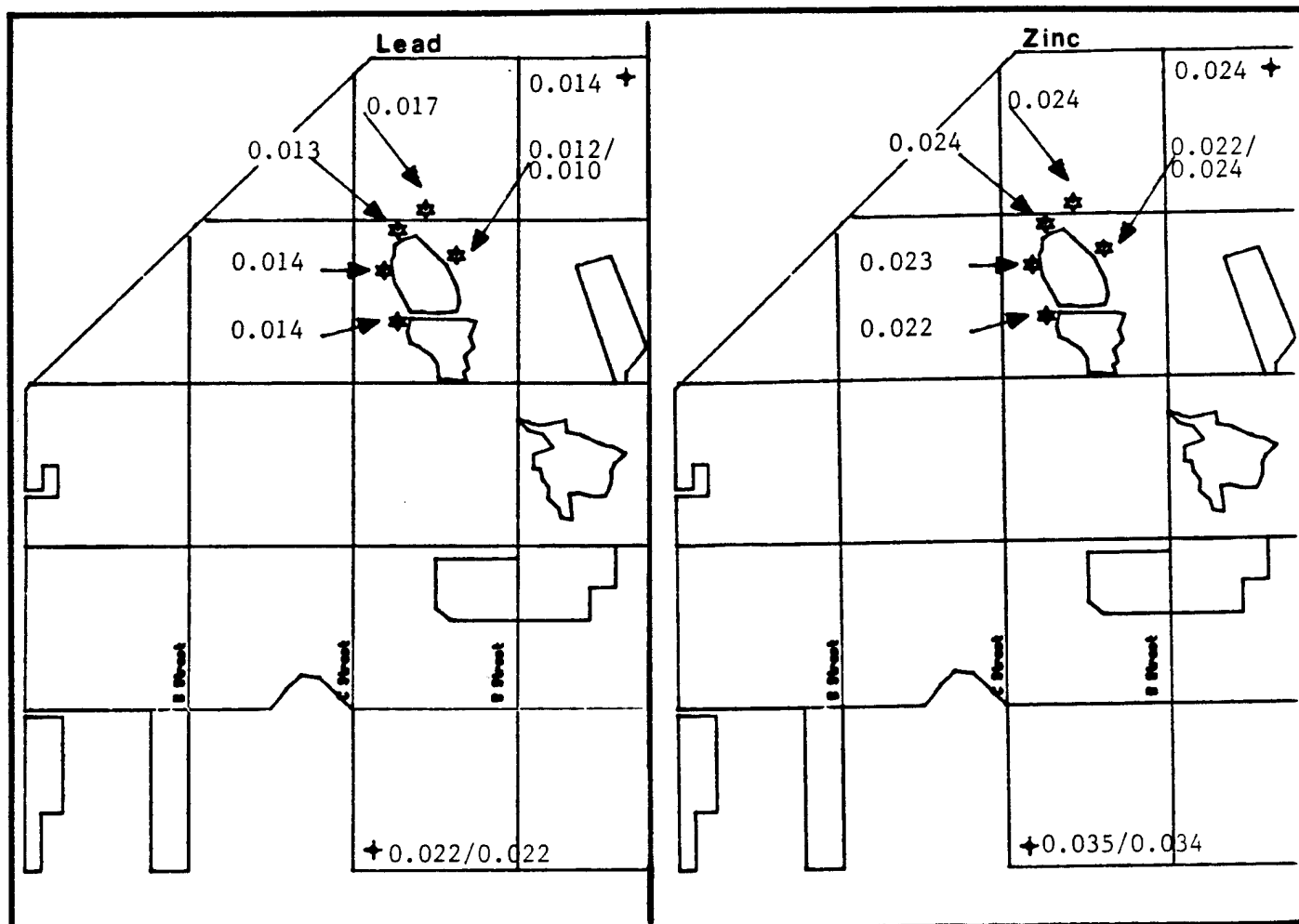
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Figure 4.3-6a

X/Q Dispersion Pattern, Wind Rose and Metals
Concentrations for November 18, 1989

($\mu\text{g}/\text{m}^3$)



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Figure 4.3-6b

**X/Q Dispersion Pattern, Wind Rose and Metals
Concentrations for November 18, 1989**

($\mu\text{g}/\text{m}^3$)

concentrations of that analyte. It appears that the high particulates and metals concentrations measured on this day had their source from outside RMA.

4.3.3.2 Metals High Event: September 14, 1990

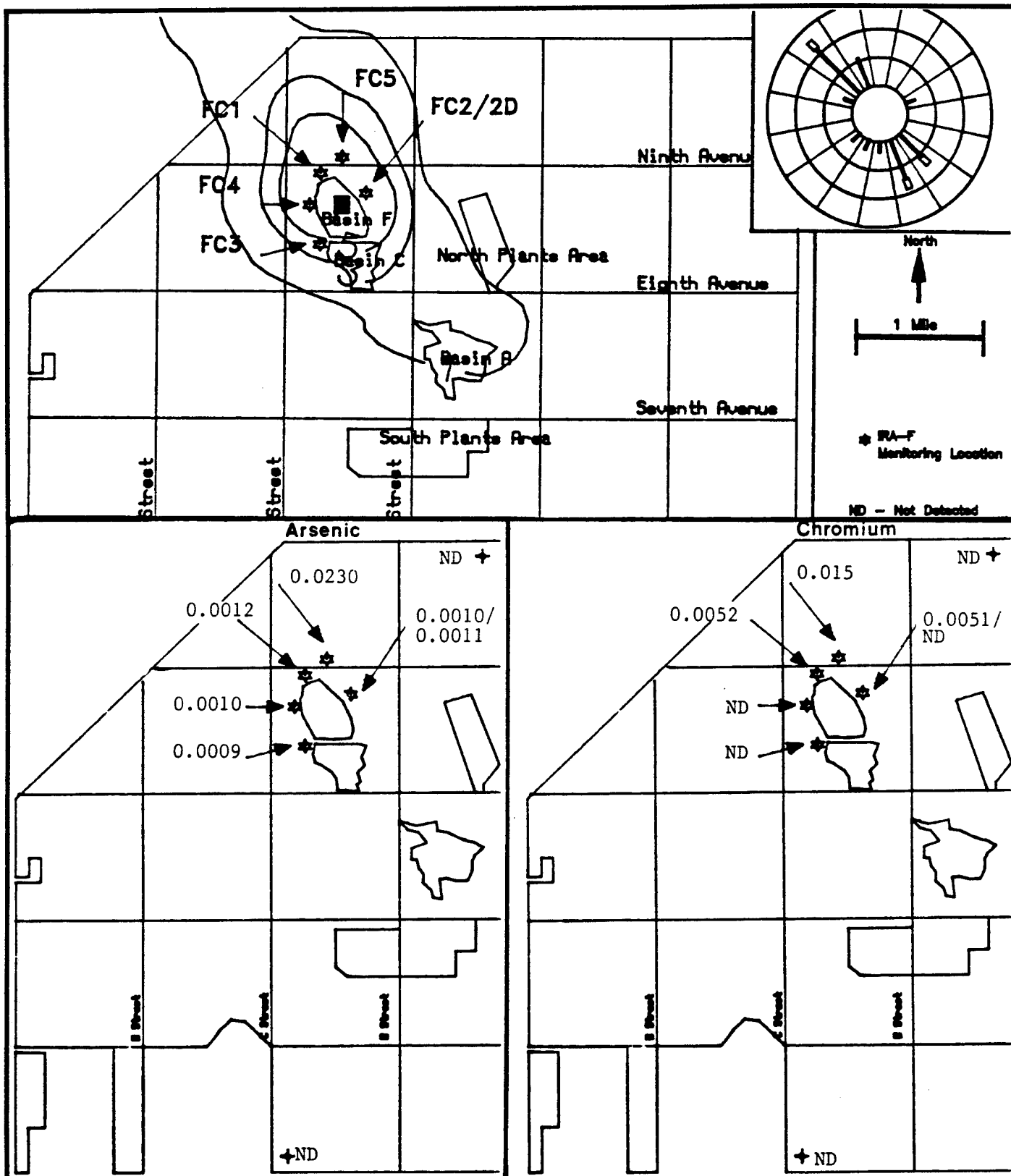
On September 14, 1990, unusually high particulates were recorded throughout the Denver metropolitan area, including RMA. The high particulates results were reflected in the correspondingly high metals results. Figures 4.3-7a and 4.3-7b show the X/Q dispersion pattern, the corresponding wind rose, and the reported IRA-F metals concentrations for this day. Again, this day is the same as the extreme TSP and PM-10 day cited in Section 4.1.3.1.2. See that section for details on meteorological conditions.

Chromium, lead, and arsenic concentrations were highest at FC-5, but only the chromium level of $0.015 \mu\text{g}/\text{m}^3$, was significantly higher than the other IRA-F sites. The arsenic concentrations detected at all sites were higher than the historical RMA average of approximately $0.0008 \mu\text{g}/\text{m}^3$. Comparison with the CMP sites shows much higher concentrations of copper, $0.206 \mu\text{g}/\text{m}^3$ at AQ3 and $0.200 \mu\text{g}/\text{m}^3$ at AQ5B, while zinc levels were similar. Zinc values must always be used with caution due to the evident zinc contamination in the filters. The CMP sites recorded much higher concentrations of zinc and copper than the IRA-F sites.

No clear pattern of metals impacts can be developed for the day in light of the prevailing meteorological conditions and the sporadic nature of the metals detections among the sampled sites. As suggested under the TSP discussion for this day, vehicular traffic impacted some of the metals concentrations at FC-5. Because chromium, lead, and arsenic were not detected at the CMP boundary sites, it is likely that there was a source internal to RMA. Basin A, which was upwind for a portion of the day, is a known low-level source for arsenic.

4.3.4 Comparison With Other Local Metals Data

The RI program collected and analyzed metals samples during 16 separate high events from April through September 1987. Sampling was generally conducted around Basin A and at three RMA



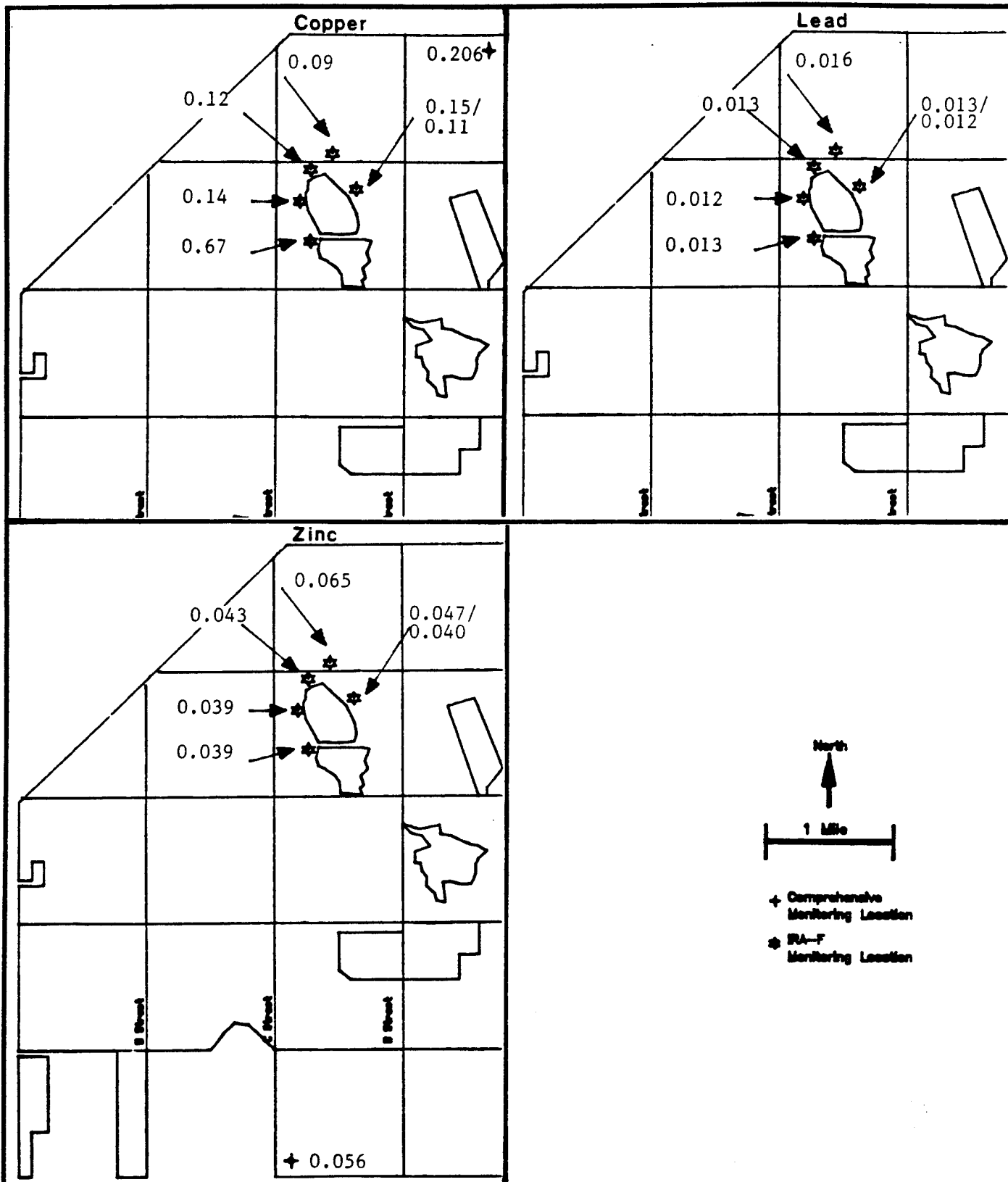
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Figure 4.3-7a

X/Q Dispersion Pattern, Wind Rose and Metals
Concentrations for September 14, 1990

($\mu\text{g}/\text{m}^3$)



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Figure 4.3-7b

X/Q Dispersion Pattern, Wind Rose and Metals
Concentrations for September 14, 1990

($\mu\text{g}/\text{m}^3$)

boundary sites (AQ1, AQ3, and AQ5). All ICAP metals analytes were detected at some point in this effort. A total of 87 samples were analyzed and showed the following results: copper was detected in 81 samples, with a maximum value of $0.91 \mu\text{g}/\text{m}^3$ and lead was detected in 66 samples, with a maximum value of $0.062 \mu\text{g}/\text{m}^3$. Basin A was identified as a potential source, especially for copper. The former Basin F area was sampled four times and during two episodes relatively high copper values were obtained. On those 2 days Basin F was a likely source of copper, but this pattern was not confirmed on the other two Basin F sample days, when copper levels at the former Basin F were roughly comparable to other RMA values.

Results from the CMP confirmed that Basin F was a likely source of chromium and to a lesser extent, a source of copper and zinc during Phase 1. At sites that were a mile or more from Basin F, metals concentrations generally dropped to those observed at other RMA sites. During subsequent phases, there was not a clear RMA source of airborne metals evident in the CMP data.

The results of the concurrent CMP sampling generally showed low metals concentrations across RMA. The highest average concentrations of most metals occurred at AQ1 and AQ2 on the western boundaries of RMA. These locations are close to an off-site local highway. For example, the FY90 maximum average cadmium level was $0.0021 \mu\text{g}/\text{m}^3$ measured at AQ2, and the maximum 24-hour concentration was $0.0281 \mu\text{g}/\text{m}^3$, measured at AQ5, on the southern boundary.

In contrast to the IRA-F sites, in FY90 the CMP sampling detected chromium at only one site, AQ5, which had a maximum annual concentration of $0.0044 \mu\text{g}/\text{m}^3$ and a 24-hour maximum of $0.0151 \mu\text{g}/\text{m}^3$. In FY88 chromium was detected at AQ3, and in FY89 at AQ7 and AQ12. No specific pattern has developed for chromium detection among the CMP sites, establishing that the chromium detected around the former Basin F is likely the product of a localized source.

While the highest average copper level of $0.0922 \mu\text{g}/\text{m}^3$ occurred in the Basin F area, the maximum 24-hour value of $0.2450 \mu\text{g}/\text{m}^3$ was recorded at AQ3 which is located at the northern RMA boundary. Copper levels at other sites across RMA were only slightly less than these values. During the previous monitoring years of FY88 and FY89, the highest copper levels were also measured at AQ3.

Lead measurements were highest at AQ2 (highest annual average value of $0.033 \mu\text{g}/\text{m}^3$) and at AQ5 (24-hour maximum of $0.0621 \mu\text{g}/\text{m}^3$). Both are RMA boundary sites, with AQ2 adjacent to a local highway and AQ5 in an area frequently impacted by the influx of emissions from the Denver area traffic. Measurements from previous years of monitoring confirm this pattern.

The maximum concentrations of zinc were also measured at RMA boundary stations. Site AQ1 recorded the highest maximum average of zinc at $0.0371 \mu\text{g}/\text{m}^3$, and the 24-hour maximum of $0.1086 \mu\text{g}/\text{m}^3$ was recorded at AQ5. The results from FY88 and FY89 showed similar high readings at these sites.

4.3.5 Metals Sources

A comparison of the metals concentrations by phase can be used to identify Basin F as a source of specific compounds. High levels of a compound in Phase 1, during remedial activity in the basin, implicated Basin F as a Phase 1 source. Since the source was essentially terminated at the conclusion of Phase 1 by sealing off the basin with clay and topsoil caps, subsequent reduction in concentrations in Phase 2 confirmed Basin F as a Phase 1 source. Additional reductions continuing into Phase 3 were expected since final capping activities of the basin area were not completed until the end of Phase 2. A second approach to determining the impact of Basin F as a source of metals was to compare the mean concentrations at both the predominantly upwind and downwind site. If the downwind site showed consistently higher concentrations than the upwind sites, the basin was the most likely metals source. Finally, comparison of the concentrations at sites in close proximity to Basin F with those from sites farther away provides information concerning the nature of Basin F as a source.

The only metal for which Basin F was clearly a primary source during Phase 1 was chromium. Zinc and copper levels reflected impacts from Basin F as well, but to a much lesser degree. Chromium was frequently detected at high levels during Phase 1, particularly during the early phases of the remediation project. After conclusion of remediation, however, chromium was detected on only one sample day (the September 14, 1990 extreme event), indicating that Basin F was a negligible source for chromium during Phases 3 and 4.

Copper, lead, and zinc were present at the highest levels during the remediation phases. While zinc concentrations were clearly at lower levels during post-remediation phases, the reductions in copper and lead were quite small. However, inspection of Phase 1 mean and maximum values for copper at each site reveals that higher Phase 1 levels were reported at the Basin F perimeter sites than at the distant locations. Furthermore, at the predominantly downwind perimeter site, BF-2, the mean copper value of $0.15 \mu\text{g}/\text{m}^3$ was significantly higher than the mean of $0.09 \mu\text{g}/\text{m}^3$ at BF-3, the upwind perimeter site. Similar patterns were not clearly established in the data for lead. These results suggest that during Phase 1 Basin F was a likely source of copper and zinc, but not of lead. Impacts were localized and fell off quite rapidly with increased distance from the source. During Phases 3 and 4 of the post-remediation period, any Basin F contribution to ambient metals levels was very low or negligible.

Although levels of cadmium decreased from Phase 1 to Phase 4, variations by site and with time were quite small. This result indicates there was no nearby source of cadmium during Phase 2 through Phase 4.

Because metals were sampled as a part of TSP sampling, metals concentrations on RMA were generally related to the levels of TSP. Maximum levels were detected on days when there were also high TSP and PM-10 levels, which in turn were largely attributable to off-site sources. During remediation activities, Basin F appeared to be a source of chromium, copper and zinc, while concentrations decreased rapidly with distance from Basin F. Furthermore, following closure of the basin, the metals levels declined to those typical of regional baseline conditions.

Figure 4.3-8 illustrates the mean monthly concentrations of all samples at all sites for selected metals during Phase 4 (FY90), the one complete year of post-remedial data collection. Metals generally show a seasonal cycle, with the highest readings during the late summer and fall. The pattern is more distinct in Figure 4.3-9, which compares the combined (or sum of) mean monthly metals concentrations with the mean monthly TSP concentrations. The seasonal pattern here was distinct, with the lowest concentrations occurring during the wetter spring months when a snow cover was likely, and increasing concentrations with the onset of the summer months. The average fall concentrations were highest and reflected the coincidence of dry weather and strong inversion conditions. Once the inversion season passed, there was a decrease in trapped pollutants in the Denver metropolitan area, and air quality improved. This trend was mirrored by the concurrent drop in particulates and metals concentrations.

4.4 ARSENIC

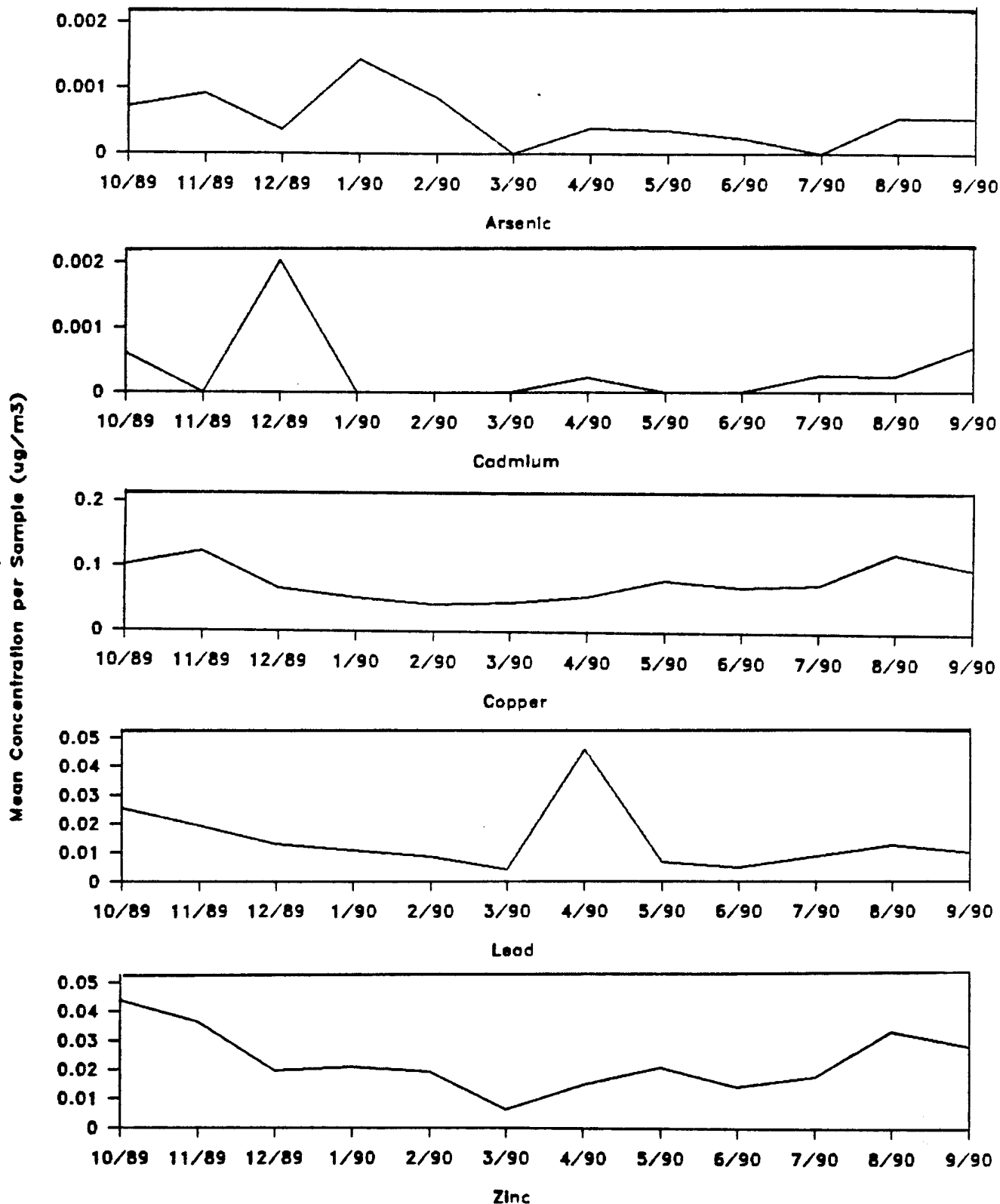
Arsenic was also analyzed from the TSP filters following their gravimetric analyses. Sampling was scheduled on a 12-day cycle throughout the IRA-F program. Because arsenic samples were analyzed under a separate method from the ICAP metals, the results are discussed separately.

4.4.1 Recovery of Arsenic Samples

Because arsenic and the other metals were analyzed using the TSP media, the recovery percentage of arsenic samples was the same as for TSP except when laboratory problems were encountered. Table 4.4-1 shows the percent recovery of arsenic samples. The relatively low recoveries of arsenic were due to power outages at FC-1 and high zinc background levels in several of the filters, which precluded a valid arsenic analysis. (Refer to Section 5.5 for further details.) Recoveries at other sites were within the regulatory guidelines, and the recovery rates for FY90 (Phase 4) were substantially above the overall total shown here.

4.4.2 Mean Arsenic Concentrations

Mean concentrations of arsenic are shown in Table 4.4-2. Levels of arsenic show a fairly even distribution at all sites during each phase. Although during Phase 2 the arsenic levels for some

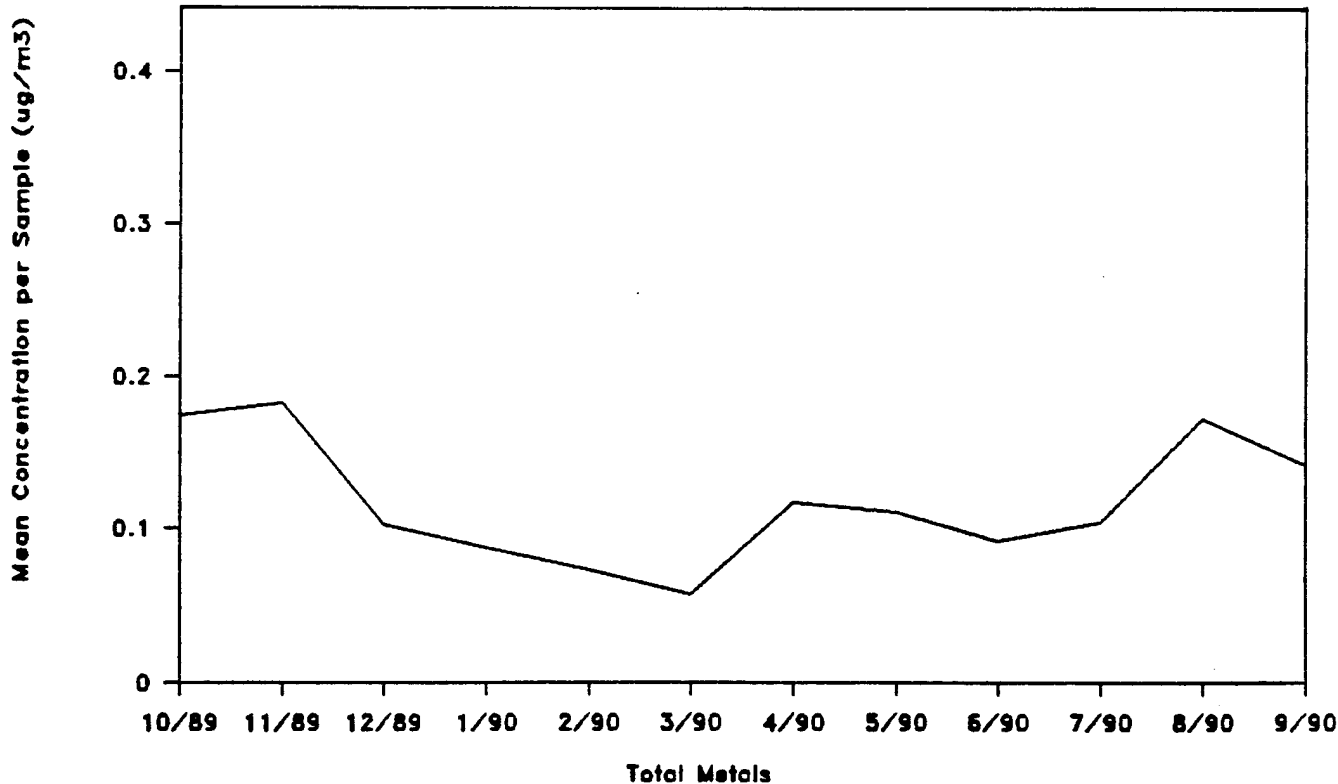
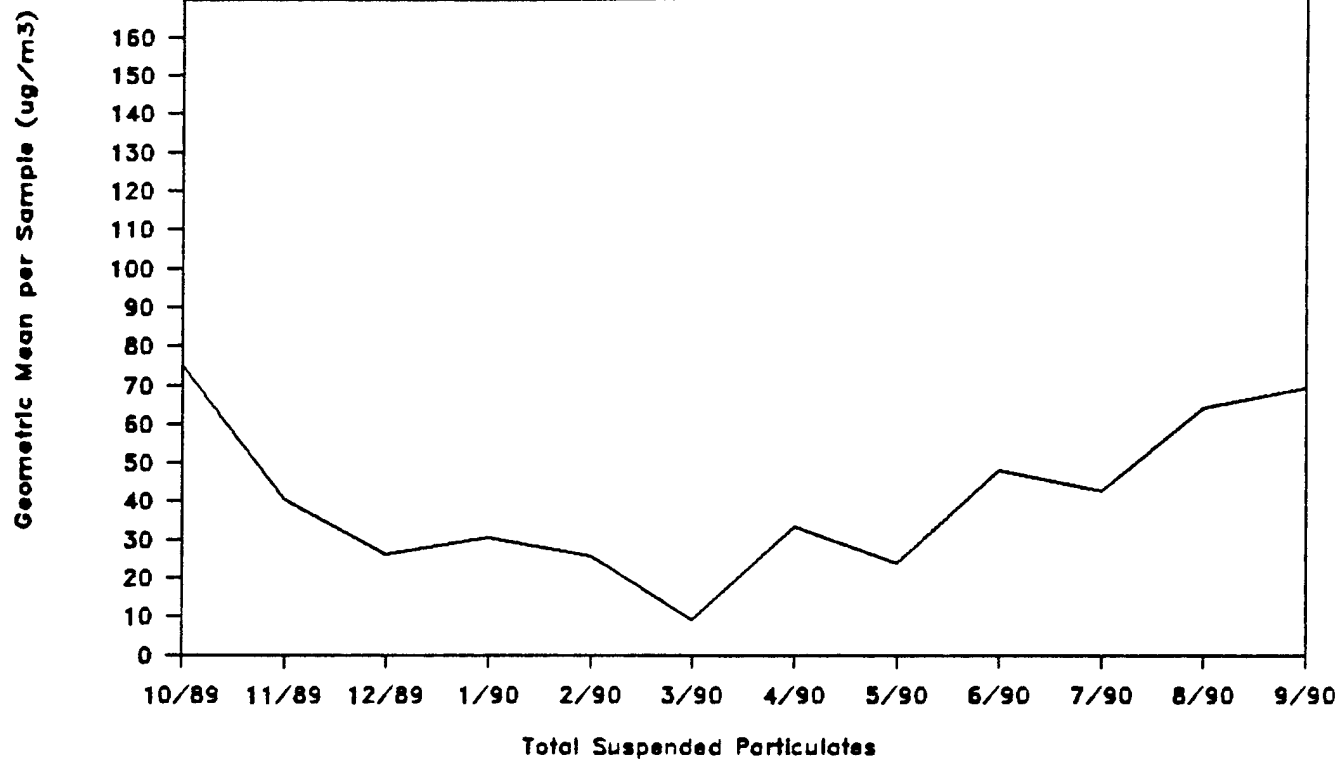


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Figure 4.3-8

Mean Monthly Metals Concentrations
for Phase 4 (FY90)



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Figure 4.3-9

**Mean Monthly TSP and Mean Monthly Total
Metals Concentrations for Phase 4 (FY90)**

Table 4.4-1 Recovery of IRA-F Arsenic Samples

STATION	NUMBER OF SAMPLES IN PERIOD	NUMBER OF VALID SAMPLES	RECOVERY PERCENT
FC-1	43	32	74.4
FC-2	43	38	88.4
FC-2D	43	38	88.4
FC-3	43	37	86
FC-4	43	37	86
FC-5	40	34	85
BF-5	5	5	100
BF-7	5	5	100
RIFS1	5	5	100
All Stations	270	231	85.6

Table 4.4-2 Arithmetic Mean Arsenic Concentrations ($\mu\text{g}/\text{m}^3$) at Basin F/IRA-F Sampling Locations

Station	SAMPLING PHASE				
	Phase 1	Phase 2 Stage 1	Phase 2 Stage 2	Phase 3	Phase 4
BF-1/FC-1	0.0008	0.0008	0.0007	0.0005	0.0005
BF-2/FC-2	0.0009	0.0011	0.0008	0.0003	0.0005
BF-2C/FC-2D	0.0010	0.0013	0.0007	0.0003	0.0004
BF-3/FC-3	0.0007	0.0009	0.0007	0.0003	0.0005
BF-4/FC-4	0.0009	0.0009	0.0007	0.0004	0.0007
FC-5	N/A**	N/A	N/A	0.0002	0.0006
BF-5	0.0012	0.0008	ND*	0.0003	N/A
BF-6	0.0008	0.0008	0.0008	N/A	N/A
BF-7	0.0007	0.0007	ND	0.0004	N/A
RIFS1	N/A	0.0008	0.0007	0.0003	N/A
RIFS1D	N/A	0.0011	0.0005	N/A	N/A
RIFS2	N/A	0.0008	0.0009	N/A	N/A

* ND = Not detected above LCRL

** N/A = Not a target analyte this phase

sites increased, (BF-2, BF-2C and BF-3), there was an overall decrease in mean concentrations at all sites from Phase 1 through Phase 4. At the four Basin F perimeter sites, the overall average Phase 4 arsenic concentration was about 60 percent of the Phase 1 value. The mean and maximum arsenic levels for each site by phase are shown in Figure 4.4-1.

4.4.3 Maximum Arsenic Concentrations

Table 4.4-3 provides 24-hour maximum arsenic concentration data. Maxima generally occurred at site FC-2/BF-2, the only significant exceptions were one very high concentration at BF-5 in Phase 1 and a relatively high level at FC-4 in Phase 4. It is also noteworthy that sites RIFS1, RIFS1D and RIFS2, which were a mile or more away from Basin F, had maxima that were comparable to or larger than the perimeter site maxima. There is no consistent spatial or temporal pattern in the maximum arsenic concentrations.

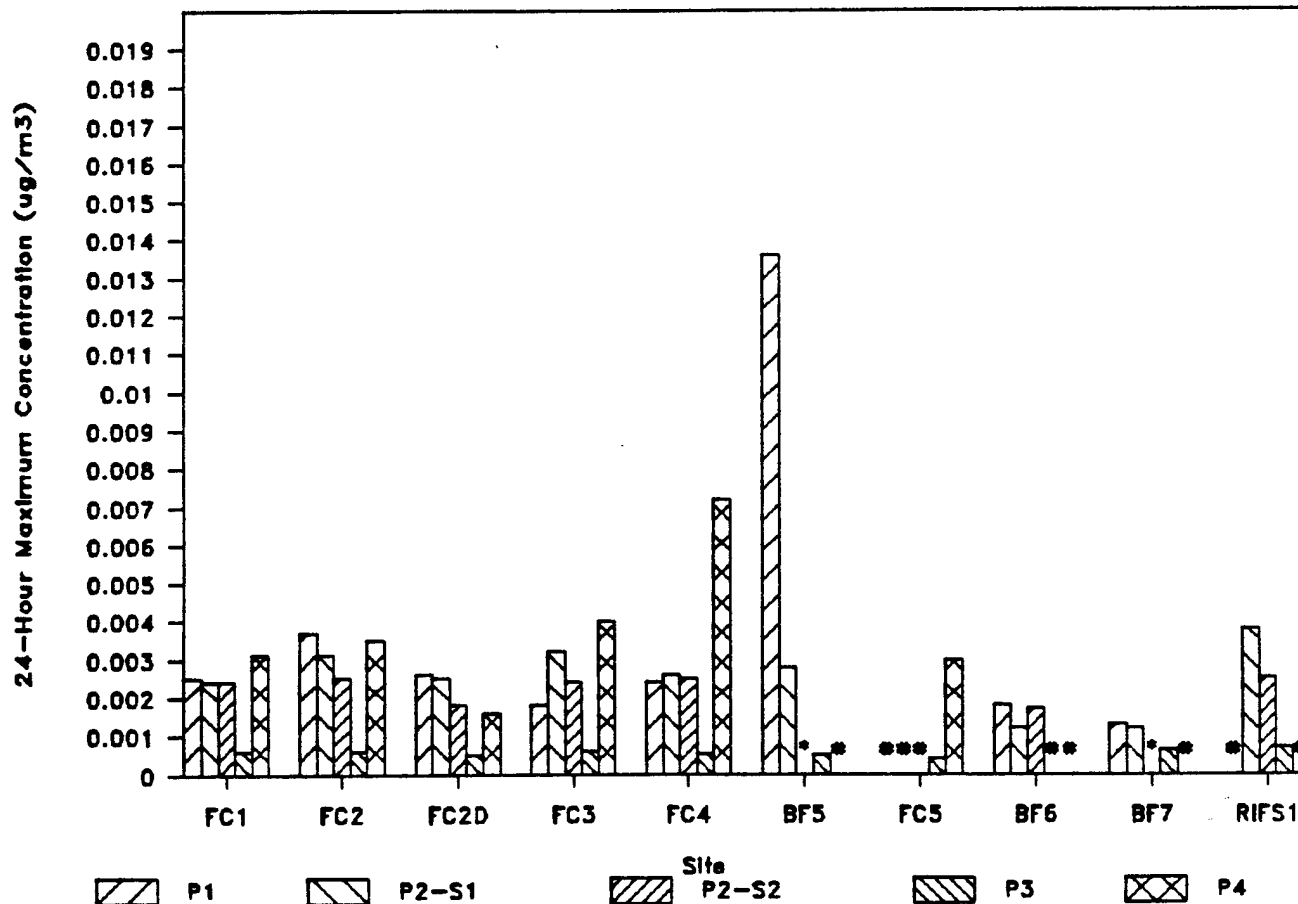
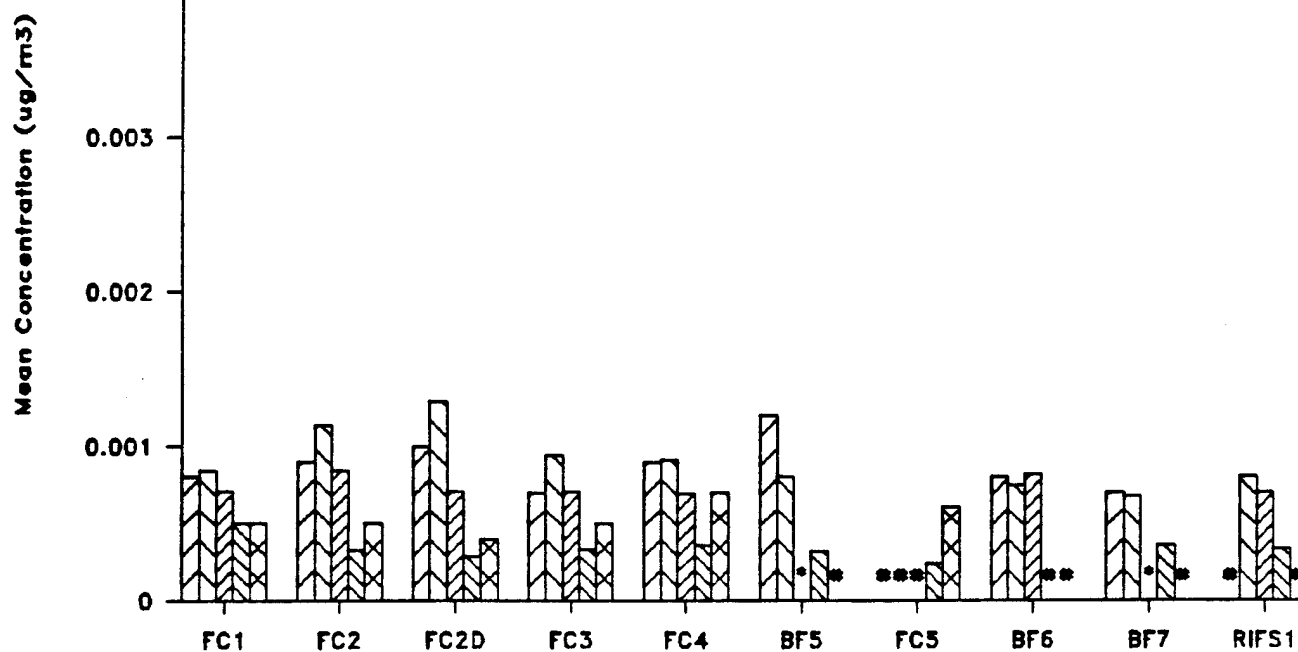
4.4.4 Other Arsenic Sampling Programs

Arsenic was detected in two of sixteen separate sampling episodes under the RI program. Both detections were near the southwest edge of Basin A during the early summer of 1987. The reported concentrations were $0.005 \mu\text{g}/\text{m}^3$ and $0.012 \mu\text{g}/\text{m}^3$.

Because the detection limit for the RI program ($0.003 \mu\text{g}/\text{m}^3$) was substantially higher than that of IRA-F, it is difficult to draw any conclusions regarding the long-term changes. However, the results confirm the rather sporadic nature of peak values in the ambient arsenic concentrations. Arsenic was also sampled under the CMP both prior to and concurrent with the IRA-F program. During all three monitoring years the CMP reported maximum arsenic concentrations near Basin A. Average and maximum levels recorded by the CMP tend to confirm the Basin F and IRA-F results.

4.4.5 Arsenic Sources

Ambient monitoring data for arsenic do not show strong impacts from Basin F during any phase. While mean values were lower in Phases 3 and 4 than during Phase 1, levels were fairly uniform



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Figure 4.4-1

Mean and Maximum Concentrations for Arsenic
by Site, by Phase

*Not Detected

Not an Analyte This Phase

Table 4.4-3 24-Hour Maximum Arsenic Concentrations ($\mu\text{g}/\text{m}^3$) at Basin F/IRA-F Sampling Locations

Station	SAMPLING PHASE				
	Phase 1	Phase 2 Stage 1	Phase 2 Stage 2	Phase 3	Phase 4
BF-1/FC-1	0.0025	0.0024	0.0024	0.0006	0.0031
BF-2/FC-2	0.0037	0.0031	0.0025	0.0006	0.0035
BF-2C/FC-2D	0.0026	0.0025	0.0018	0.0005	0.0016
BF-3/FC-3	0.0018	0.0032	0.0024	0.0006	0.004
BF-4/FC-4	0.0024	0.0026	0.0025	0.0005	0.0072
FC-5	N/A**	N/A	N/A	0.0004	0.003
BF-5	0.0136	0.0028	ND*	0.0005	N/A
BF-6	0.0018	0.0012	0.0017	N/A	N/A
BF-7	0.0013	0.0012	ND	0.0006	N/A
RIFS1	N/A	0.0038	0.0025	0.0007	N/A
RIFS1D	N/A	0.0039	0.0007	N/A	N/A
RIFS2	N/A	0.0034	0.0023	N/A	N/A

* ND = Not detected above LCRL

** N/A = Not a target analyte this phase

at all sites during each phase. Therefore, although the arsenic concentrations were smaller in Phases 3 and 4, there is no evidence pointing to the former Basin F as a source of the extreme levels. Furthermore, overall 24-hour maximum values at several sites actually occurred during Phase 4, suggesting that there were only intermittent periods during which an alternative source might have been active. The source of the arsenic intermittently detected by IRA-F samplers may have been attributable to sporadic excavation and drilling activities on RMA, or to Basin A during periods of high winds, when the wind direction was such that former Basin F was downwind from Basin A. Alternatively, the high levels may have been due to outside sources.

Sampling data collected by the CMP have clearly implicated Basin A as a low-level source of arsenic. The highest concentrations of arsenic found in the vicinity of Basin A were a maximum average concentration of $0.0005 \mu\text{g}/\text{m}^3$ and a 24-hour maximum of $0.0042 \mu\text{g}/\text{m}^3$. Both these values were recorded from a high event sample episode at a mobile sampler placed at the edge of Basin A. During FY88 and FY89, the highest arsenic concentrations measured at a CMP site were at AQ8, which is located at the southeast edge of the Basin A area. The high event sampling was normally performed during high wind conditions, because these conditions enhanced analyte suspension. The high event sampling gives results which are above average, or conservative.

Ambient arsenic concentrations decreased somewhat after completion of remedial activities, but even the more distant sites exhibited concentrations equivalent to the sites immediately adjacent to former Basin F. An external source of ambient arsenic is likely, as indicated by nearby CERCLA remediation sites having reported high background levels of arsenic. Arsenic was known to exist on RMA, but its industrial and household uses allow it to enter the atmosphere from numerous other small sources which may have contributed to the detections at RMA.

4.5 MERCURY

Mercury was sampled at the Basin F sites during all phases. During IRA-F, the sampling frequency was originally set at a 6-day cycle, but this frequency was reduced to a 12-day cycle

for the latter part of Phase 3 and all of Phase 4. Mercury samples were collected on one of the GMW VOTA samplers and, consequently, were collected from noon to noon.

4.5.1 Recovery of Mercury Samples

Mercury sample recoveries are presented in Table 4.5-1. The lowest percentage of recovery was 83 percent for FC-1. The average recovery rate of 87.6 percent was within acceptable limits. A large number of scheduled samples were not collected because mercury sampling media were unavailable for a portion of the project.

4.5.2 Mean Mercury Concentrations

Mean mercury concentrations at all sites are shown in Table 4.5-2. Concentrations were fairly uniform during Phase 1, decreased in magnitude in Phase 2, and were not detected in Phase 3 and most of Phase 4. Several detections occurred, however, during the summer of 1990. The reported Phase 4 average values may be somewhat spurious when there was a mix of values both above the LCRL and below it. When there was a mix of concentrations reported both above and below the LCRL, the average was computed using the actual reported values above the LCRL, and an arbitrary value of one-half the LCRL for those samples reported as below the LCRL. Thus, the averages were computed from a combination of actual and estimated values. The mean levels were quite low, but the Phase 4 detections which were reported must be considered questionable due to similar sample mass values reported for field blanks (see Section 5.2.1.4 for further details). Mean and maximum values for mercury by site, by phase are graphically depicted in Figure 4.5-1.

4.5.3 Maximum Mercury Concentrations

Table 4.5-3 presents the 24-hour maximum concentrations for mercury. During Phase 1, two extreme values of mercury were detected, with values reported above 400 $\mu\text{g}/\text{m}^3$. These data points were ruled invalid because they were nearly 60 times greater than other maxima and the extremes could not be substantiated by prior or subsequent analyses, or by spatial patterns. These data were attributed to laboratory or sampling error and were excluded from this analysis. The

Table 4.5-1 Recovery of IRA-F Mercury Samples

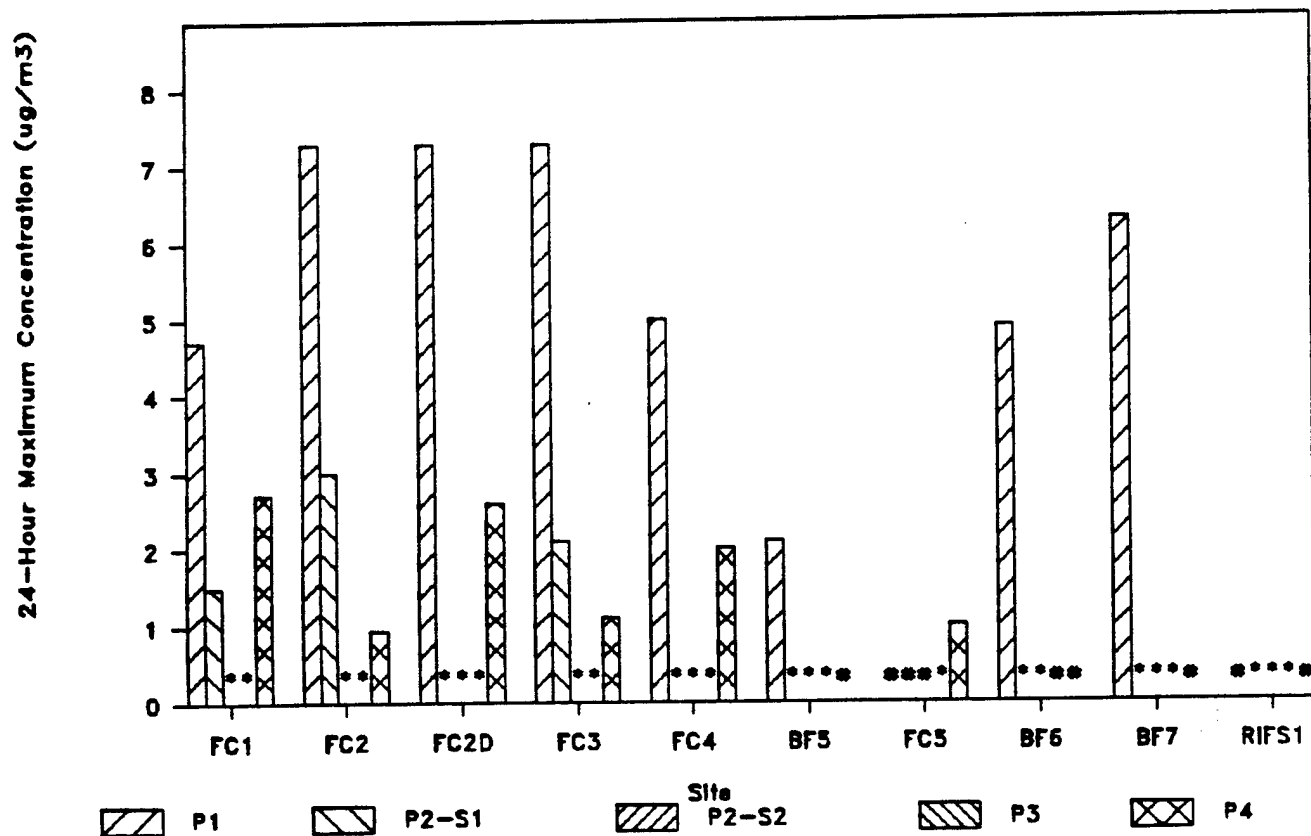
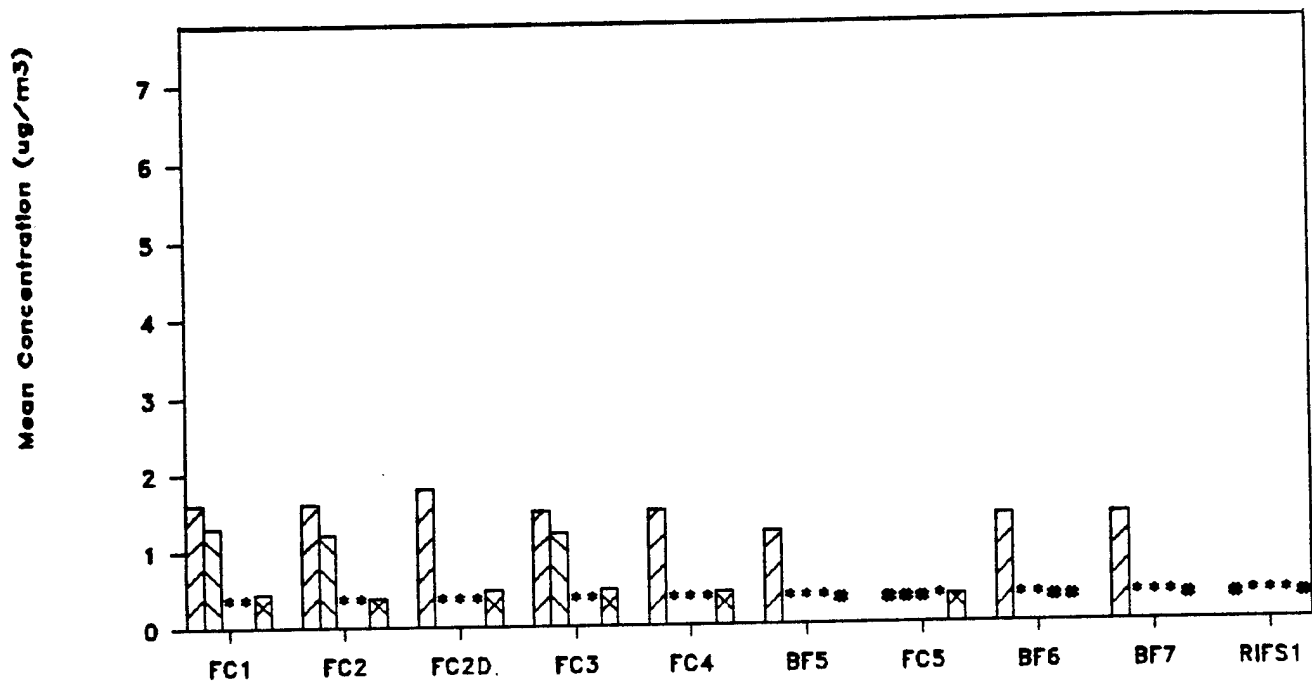
STATION	NUMBER OF SAMPLES IN PERIOD	NUMBER OF VALID SAMPLES	RECOVERY PERCENT
FC-1	47	39	83
FC-2	47	41	87.2
FC-2D	43	36	83.7
FC-3	47	41	87.2
FC-4	47	42	89.4
FC-5	41	36	87.8
BF-5	9	9	100
BF-7	9	9	100
RIFS1	9	9	100
All Stations	299	262	87.6

Table 4.5-2 Arithmetic Mean Mercury Concentrations ($\mu\text{g}/\text{m}^3$) at
Basin F/IRA-F Sampling Locations

Station	SAMPLING PHASE				
	Phase 1	Phase 2 Stage 1	Phase 2 Stage 2	Phase 3	Phase 4
BF-1/FC-1	1.6	1.3	ND*	ND	0.44
BF-2/FC-2	1.6	1.2	ND	ND	0.38
BF-2C/FC-2D	1.8	ND	ND	ND	0.47
BF-3/FC-3	1.5	1.2	ND	ND	0.47
BF-4/FC-4	1.5	ND	ND	ND	0.43
FC-5	N/A**	N/A	N/A	ND	0.36
BF-5	1.2	ND	ND	ND	N/A
BF-6	1.4	ND	ND	N/A	N/A
BF-7	1.4	ND	ND	ND	N/A
RIFS1	N/A	ND	ND	ND	N/A
RIFS1D	N/A	ND	ND	N/A	N/A
RIFS2	N/A	ND	ND	N/A	N/A

* ND = Not detected above LCRL

** N/A = Not a target analyte this phase



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Figure 4.5-1

Mean and Maximum Concentrations for Mercury
by Site, by Phase

*Not Detected

Not an Analyte This Phase

Table 4.5-3 24-Hour Maximum Mercury Concentrations ($\mu\text{g}/\text{m}^3$) at
Basin F/IRA-F Sampling Locations

Station	SAMPLING PHASE				
	Phase 1	Phase 2 Stage 1	Phase 2 Stage 2	Phase 3	Phase 4
BF-1/FC-1	4.7	1.5	ND*	ND	2.70
BF-2/FC-2	7.3	3.0	ND	ND	0.94
BF-2C/FC-2D	7.3	ND	ND	ND	2.60
BF-3/FC-3	7.3	2.1	ND	ND	1.10
BF-4/FC-4	5.0	ND	ND	ND	2.00
FC-5	N/A**	N/A	N/A	ND	1.00
BF-5	2.1	ND	ND	ND	N/A
BF-6	4.9	ND	ND	N/A	N/A
BF-7	6.3	ND	ND	ND	N/A
RIFS1	N/A	ND	ND	ND	N/A
RIFS1D	N/A	ND	ND	N/A	N/A
RIFS2	N/A	ND	ND	N/A	N/A

* ND = Not detected above LCRL

** N/A = Not a target analyte this phase

valid data show a fairly uniform distribution of maximum values within each phase, with an extended period from May 1989 through mid-June 1990 when mercury was not detected above the LCRL. Mercury was detected in ambient samples during the summer of 1990, but as noted above, these data cannot be used with confidence.

4.5.4 Other Sampling Efforts

During the RI program of 1986-1987, there were a total of 16 sample events which included mercury sampling. Sampling generally focused on Basin A and the RMA boundary sites (AQ1, AQ3, and AQ5). There were no reports of mercury above the detection limit. Under the CMP, mercury was also sampled on a "high event" schedule, and during Phases 1 through 3, the CMP results mirrored the Basin F results cited above. During Phase 4, the CMP sampled for mercury on 12 high events. Mercury sampling was conducted at eight sites on four separate episodes during the summer of 1990 (June 13, July 26, September 20, and September 26). Sampling was conducted once each around the former Basin F and the South Plants subdrain facility, and twice around Basin A. The CMP sampling did not detect mercury above the LCRL.

4.5.5 Mercury Sources

During Phase 1, Basin F was evidently a source for mercury. Concentrations during this phase were higher at the Basin F perimeter sites than at the off-site locations, showing that impacts were strongest in the immediate vicinity of Basin F. Phase 2 yielded detections of mercury during Stage 1 at three sites only, but no detections at any site during Stage 2, indicating Basin F impacts decreased after Phase 1. For the entire Phase 3 and most of Phase 4, there were no detections of mercury, which suggests there were no significant sources impacting the sampling area.

Throughout the summer of 1990, there were several mercury detections in ambient samples and in field blanks. All sites yielded detections, and the mean values were fairly uniform. Due to the detection of mercury in field blanks, the presence of an on-site source is questionable.

Throughout the CMP FY90 sampling program, a total of 117 mercury samples were collected. There were no detections above the LCRL of 0.089 $\mu\text{g}/\text{m}^3$. Although mercury sampling was conducted across RMA in Phase 4, no potential sources were identified under the CMP.

4.6 VOLATILE ORGANIC COMPOUNDS

Sampling for VOCs has extended from the RI program through the Basin F remedial activity to the IRA-F and CMP air monitoring programs. A formidable effort was required to interpret the VOC results, largely because there were different sampling strategies and different analytical techniques, and even different data processing schemes for the different programs.

A total of 22 target analytes was included for the IRA-F program. This list is identical to that which was used for the odor sampling program and is nearly the same as the one used by the CMP. There were, however, substantial differences from the Basin F sampling program. All programs involved trapping VOCs on a Tenax sampling medium and have used two tubes in series for collecting the sample. The first tube contained Tenax and the second contained Tenax-and-charcoal. Under Basin F and under the CMP (until summer 1990) the media of the two tubes were desorbed together at the laboratory and the results were reported as a single number. Under the odor sampling program and IRA-F, the two tubes were desorbed separately and the results were added together as a part of the data processing effort. When the CMP changed analytical laboratories during the summer of 1990, the desorption scheme was changed to an analysis of the first tube, followed by analysis of the second tube only when significant breakthroughs occurred on the first tube. A minimum of 10 percent of the backup tubes were analyzed under this program.

Since the laboratory's analysis of a VOC tube was done in a single desorption; there was no capability to dilute and reanalyze samples of VOCs as there was with metals and OCPs. Additionally, VOC results which were not within the certified reporting range of the laboratory, must be reported as "estimates." The estimated values must be interpreted as less reliable than

the certified values. For the analyses in this report, both the certified and estimated values were reported and were combined to calculate extremes and average values. A listing of all IRA-F values, including both certified and estimated values, is provided in Appendix B.

In Subsections 4.6.2 and 4.6.3 the mean and extreme maximum values are reported and discussed. Actual concentrations are presented in tabular form to provide a final documentation of results. For interpretation of each target analyte, however, a supplementary section (4.6.4) is included to present a more detailed interpretation for selected individual target compounds.

4.6.1 Recovery of Volatile Organic Compounds Samples

Valid data recovery of VOCs under the IRA-F program was generally quite high, with an overall recovery rate was 89.8 percent. Recovery rates for VOCs for each site in the IRA-F program are provided in Table 4.6-1. Sampler malfunctions for VOCs rarely contributed to sample loss; however, the breakage of the glass media tubes was the main cause of sample loss.

4.6.2 Mean Volatile Organic Compounds Concentrations

Results of VOC sampling are presented in Table 4.6-2, which gives the mean concentrations by phase and site for each target compound. Concentrations of most compounds decreased over time, after Phase 2, Stage 2. Compounds showing little or no decrease with time were carbon tetrachloride, 1,2-dichloroethane, methyl ethyl ketone, and methyl isobutyl ketone. Most of the reductions in the other compounds occurred from Phase 1 to Phase 2, Stage 1, although there generally were further reductions through Phase 3. Compounds that dropped from detectable levels to predominantly nondetectable levels were bicycloheptadiene, dicyclopentadiene, chlorobenzene and dimethyl disulfide. Other compounds that decreased from Phase 1 to Phase 4 were benzene, 1,1,1-trichloroethane, chloroform, ethylbenzene, methylene chloride, tetrachloroethylene, toluene, trichloroethylene, and xylenes. For all other compounds, with the exception of chlorobenzene and methylene chloride, Phase 4 concentrations were higher than those in Phase 3. A possible cause for the increases in Phase 4 may include different meteorological conditions. Phase 3 covered only the summer months, while Phase 4 also

Table 4.6-1 Recovery of IRA-F Volatile Organic Compounds Samples

STATION	NUMBER OF SAMPLES IN PERIOD	NUMBER OF VALID SAMPLES	RECOVERY PERCENT
FC-1	85	73	85.9
FC-2	85	76	89.4
FC-2D	43	41	95.3
FC-3	85	76	89.4
FC-4	85	77	90.6
FC-5	79	73	92.4
BF-5	9	7	77.8
BF-7	9	7	77.8
RIFS1	9	9	100
All Stations	489	439	89.8

Table 4.6-2 Arithmetic Mean VOC Concentrations ($\mu\text{g}/\text{m}^3$) at Basin F, RIFS and IRA-F Sampling Locations

	ACET	C6H6	BCHPD	CCL4	111TCE	112TCE	CHCL3	CLC6H5	DCPD	11DCLE	12DCLE	DBCP	NNDMEA
Phase 1 (3/22/88 - 12/12/88)													
BF-1	9.02	2.45	1.82	0.65	9.44	ND*	2.14	0.05	1.60	ND	0.04	N/A	N/A
BF-2	9.87	3.49	9.96	0.61	8.05	ND	6.95	0.12	4.53	0.02	0.30	N/A	N/A
BF-2C	5.78	2.94	8.84	0.38	7.12	ND	5.24	0.08	3.42	ND	ND	N/A	N/A
BF-3	8.36	1.94	0.49	0.52	6.94	ND	0.80	ND	0.52	ND	0.03	N/A	N/A
BF-4	9.38	2.54	0.55	0.42	10.53	0.05	0.91	0.03	0.48	ND	ND	N/A	N/A
BF-5	12.50	2.19	0.43	0.53	8.54	ND	0.88	0.02	0.34	ND	0.03	N/A	N/A
BF-6	11.23	1.86	0.11	0.33	8.82	ND	0.30	ND	0.05	ND	0.02	N/A	N/A
BF-7	14.25	2.15	0.03	0.36	6.24	ND	0.14	ND	0.03	ND	0.02	N/A	N/A
RIFS1	N/A**	4.00	0.09	0.47	1.95	ND	0.34	0.03	0.35	ND	0.05	0.08	ND
Phase 2 - Stage 1 (12/13/88 - 2/15/89)													
BF-1	13.62	3.97	0.25	1.04	5.50	ND	0.77	0.02	0.45	ND	ND	N/A	N/A
BF-2	11.82	3.79	0.88	0.92	5.85	ND	1.89	0.03	0.32	ND	0.06	N/A	N/A
BF-2C	13.33	3.85	0.12	1.11	7.93	ND	0.73	ND	0.08	ND	ND	N/A	N/A
BF-3	9.42	3.32	0.09	0.88	5.03	ND	0.48	ND	0.18	ND	0.02	N/A	N/A
BF-4	13.55	3.78	0.13	0.75	5.22	ND	0.39	ND	0.21	ND	0.03	N/A	N/A
BF-5	7.93	2.45	0.47	0.97	4.18	ND	0.33	ND	0.06	ND	0.02	N/A	N/A
BF-6	8.37	3.24	0.06	1.23	4.73	ND	0.35	ND	ND	ND	0.03	N/A	N/A
BF-7	8.61	3.51	0.03	1.20	5.26	ND	0.35	0.03	0.04	ND	0.02	N/A	N/A
RIFS1	N/A	5.89	ND	1.35	2.77	ND	0.31	0.04	ND	ND	0.24	ND	ND
RIFS1D	N/A	7.32	ND	1.74	3.41	ND	1.44	0.03	ND	ND	0.16	ND	ND
RIFS2	N/A	4.95	0.03	1.99	2.49	ND	1.08	0.03	ND	ND	0.36	ND	ND
Phase 2 - Stage 2 (2/16/89 - 5/5/89)													
BF-1	7.78	2.00	0.06	0.78	3.50	ND	0.30	0.03	0.13	ND	0.03	N/A	N/A
BF-2	6.90	1.65	0.03	0.70	2.57	ND	0.37	0.02	0.04	ND	0.02	N/A	N/A
BF-2C	20.79	1.01	0.06	0.58	3.19	0.46	0.31	ND	ND	ND	ND	N/A	N/A
BF-3	6.71	1.71	0.03	0.68	2.54	ND	0.18	0.02	0.03	ND	0.03	N/A	N/A
BF-4	6.36	2.15	0.04	0.67	2.42	ND	0.17	ND	0.03	ND	0.02	N/A	N/A
BF-5	3.71	1.19	0.02	0.51	1.89	0.19	0.15	0.03	ND	ND	0.02	N/A	N/A
BF-6	3.95	1.41	ND	0.70	2.17	ND	0.18	0.03	ND	ND	ND	N/A	N/A
BF-7	6.49	1.70	0.02	0.76	3.40	ND	0.13	0.03	ND	ND	0.02	N/A	N/A
RIFS1	N/A	2.10	ND	0.63	1.64	ND	0.11	0.03	ND	ND	0.04	ND	ND
RIFS1D	N/A	2.28	ND	0.53	1.22	ND	0.11	0.04	ND	ND	0.06	ND	ND
RIFS2	N/A	2.37	ND	0.89	1.30	ND	0.14	ND	ND	ND	0.08	ND	ND
Phase 3 (5/6/89 - 9/30/89)													
FC-1	N/A	1.15	ND	0.35	1.09	ND	0.15	0.02	ND	ND	0.02	0.04	ND
FC-2	N/A	1.00	ND	0.40	1.01	ND	0.27	0.02	ND	ND	0.03	ND	ND
FC-2D	N/A	1.18	ND	0.42	1.11	ND	0.30	0.02	ND	ND	0.03	ND	ND
BF-3/FC-3	N/A	1.07	ND	0.42	1.09	ND	0.11	0.02	ND	ND	0.03	ND	ND
BF-4/FC-4	N/A	1.19	ND	0.40	1.16	ND	0.11	0.02	ND	ND	0.03	ND	ND
BF-5	N/A	1.06	ND	0.45	0.94	ND	0.10	0.03	ND	ND	0.03	0.03	ND
FC-5	N/A	0.90	ND	0.37	0.95	ND	0.18	0.02	ND	ND	0.02	ND	ND
BF-7	N/A	1.15	ND	0.42	1.25	ND	0.09	0.03	ND	ND	0.02	0.02	ND
RIFS1	N/A	1.28	ND	0.39	1.15	ND	0.12	0.03	ND	ND	0.03	ND	ND
Phase 4 (10/1/89 - 9/30/90)													
FC-1	N/A	1.36	ND	0.56	1.40	ND	0.30	0.02	ND	ND	0.06	0.02	ND
FC-2	N/A	1.33	0.04	0.58	1.41	ND	0.67	0.02	ND	ND	0.07	ND	ND
FC-2D	N/A	1.22	0.05	0.49	1.40	ND	0.69	0.02	ND	ND	0.06	0.03	ND
FC-3	N/A	1.43	0.02	0.60	1.46	0.02	0.20	0.02	ND	0.01	0.07	0.02	0.05
FC-4	N/A	1.38	ND	0.60	1.52	ND	0.18	0.02	ND	ND	0.06	0.03	ND
FC-5	N/A	1.30	0.02	0.57	1.36	ND	0.36	0.02	ND	ND	0.06	ND	ND
	DMDS	ETC6H5	HCB	MEK	CH2CL2	MIBK	T12DCE	TCLEE	MEC6H5	TRCLE	12DMB	XYLEN	T-XYLENS
Phase 1 (3/22/88 - 12/12/88)													
BF-1	7.86	1.09	N/A**	1.17	10.48	0.09	ND*	2.12	9.34	0.26	N/A	N/A	5.61
BF-2	5.34	1.58	N/A	0.79	7.57	ND	ND	5.07	20.95	0.12	N/A	N/A	8.57
BF-2C	6.69	1.56	N/A	0.89	10.47	ND	ND	3.41	23.55	0.14	N/A	N/A	7.72
BF-3	0.50	0.81	N/A	0.57	7.17	ND	ND	1.13	8.27	0.21	N/A	N/A	4.23
BF-4	0.91	0.92	N/A	0.68	6.36	ND	ND	1.13	8.51	0.29	N/A	N/A	5.02
BF-5	0.92	0.77	N/A	1.29	7.77	ND	ND	1.21	5.47	0.24	N/A	N/A	3.94
BF-6	0.04	0.78	N/A	0.79	15.89	ND	ND	1.02	7.96	0.18	N/A	N/A	4.36
BF-7	0.02	0.89	N/A	0.79	4.99	ND	ND	1.07	5.60	0.17	N/A	N/A	4.57
RIFS1	0.03	1.72	N/A	N/A	4.19	0.10	ND	1.56	8.00	0.12	2.49	2.95	5.44
Phase 2 - Stage 1 (12/13/88 - 2/15/89)													
BF-1	ND	1.59	ND	3.31	4.01	ND	ND	1.55	5.24	0.17	N/A	N/A	6.75
BF-2	0.02	1.49	ND	3.25	2.52	ND	ND	1.57	5.05	0.11	N/A	N/A	6.35
BF-2C	ND	1.28	ND	3.72	4.23	ND	ND	1.33	5.29	0.11	N/A	N/A	5.87
BF-3	ND	1.45	ND	3.64	3.52	ND	ND	1.37	4.81	0.15	N/A	N/A	6.40
BF-4	ND	1.94	ND	3.83	3.64	ND	ND	1.59	5.02	0.17	N/A	N/A	8.17
BF-5	ND	0.85	ND	2.13	2.12	ND	ND	0.94	3.30	0.09	N/A	N/A	3.72
BF-6	ND	1.02	ND	3.65	1.48	ND	ND	1.14	3.78	0.14	N/A	N/A	3.84
BF-7	ND	1.19	ND	3.61	3.07	ND	0.02	1.20	4.05	0.17	N/A	N/A	4.45
RIFS1	ND	2.00	N/A	N/A	4.42	ND	ND	1.86	8.21	0.17	2.37	5.12	7.49
RIFS1D	ND	2.36	N/A	N/A	5.39	ND	ND	2.06	10.83	0.16	3.06	6.39	9.45
RIFS2	ND	1.61	N/A	N/A	4.46	ND	ND	1.35	7.81	0.11	1.94	4.15	6.09
Phase 2 - Stage 2 (2/16/89 - 5/5/89)													
BF-1	0.02	1.07	ND	3.71	4.14	ND	ND	5.29	3.65	6.98	N/A	N/A	4.88
BF-2	ND	0.52	ND	3.09	6.11	ND	ND	0.78	2.84	0.24	N/A	N/A	2.68
BF-2C	ND	0.46	ND	2.57	19.01	ND	ND	0.66	2.82	0.14	N/A	N/A	2.64
BF-3	ND	0.58	ND	3.01	23.81	ND	ND	0.78	3.19	0.08	N/A	N/A	2.98
BF-4	ND	0.79	ND	2.96	3.23	ND	ND	0.94	3.62	0.16	N/A	N/A	3.98
BF-5	ND	0.41	ND	2.47	1.29	ND	ND	0.61	2.45	0.07	N/A	N/A	2.22
BF-6	ND	0.51	ND	2.97	2.81	ND	ND	0.65	2.82	0.05	N/A	N/A	2.87
BF-7	ND	0.61	ND	3.53	2.94	ND	ND	0.85	3.52	0.04	N/A	N/A	3.12
RIFS1	ND	0.72	N/A	N/A	2.38	ND	ND	0.93	6.10	0.06	1.03	2.27	3.30
RIFS1D	ND	0.67	N/A	N/A	1.23	ND	ND	0.82	6.66	0.04	0.88	2.87	3.75
RIFS2	ND	0.69	N/A	N/A	1.33	ND	ND	0.77	6.03	0.04	0.80	2.34	3.14
Phase 3 (5/6/89 - 9/30/89)													
FC-1	ND	0.45	N/A	N/A	0.74	0.03	ND	0.71	1.78	0.30	0.61	1.52	2.13
FC-2	ND	0.60	N/A	N/A	0.55	0.02	ND	0.61	1.80	0.04	0.57	1.38	1.95
FC-2D	ND	0.38	N/A	N/A	0.33	0.02	ND	0.54	2.10	0.03	0.53	1.33	1.86
BF-3/FC-3	ND	0.42	N/A	N/A	0.73	0.03	ND	0.55	1.65	0.04	0.57	1.38	1.95
BF-4/FC-4	ND	0.47	N/A	N/A	0.92	0.04	ND	0.70	2.20	0.04	0.63	1.55	2.18
BF-5	ND	0.36	N/A	N/A	0.31	ND	ND	0.56	1.67	0.05	0.53	1.30	1.83
FC-5	ND	0.41	N/A	N/A	1.17	0.04	ND	0.55	1.85	0.44	0.54	1.31	1.85
BF-7	ND	0.36	N/A	N/A	0.45	0.02	ND	0.69	1.98	0.03	0.49	1.29	1.78
RIFS1	ND	0.48	N/A	N/A	0.48	ND	ND	0.70	2.26	0.04	0.67	1.69	2.36
Phase 4 (10/1/89 - 9/30/90)													
FC-1	ND	0.57	N/A	N/A	0.53	0.09	ND	0.77	3.92	0.07	0.75	1.65	2.40
FC-2	ND	0.53	N/A	N/A	0.51	0.08	ND	0.92	3.71	0.05	0.72	1.66	2.38
FC-2D	ND	0.55	N/A	N/A	0.51	0.10	ND	0.80	3.56	0.05	0.73	1.44	2.17
FC-3	ND	0.60	N/A	N/A	0.50	0.10	0.02	0.89	3.62	0.06	0.78	1.61	2.39
FC-4	ND	0.65	N/A	N/A	0.56	0.10	ND	0.86	3.42	0.06	0.86	1.65	2.51
FC-5	ND	0.55	N/A	N/A	0.47	0.09	ND	0.79	3.53	0.10	0.74	1.63	2.37

incorporated the winter months which are prone to poorer dispersion conditions. In addition, minor changes in sampling techniques or actual local source changes may have contributed to Phase 4 releases. Possible local sources are the emissions from tank, pond and waste pile vents. Real-time and canister sampling suggest there may have been an increase in vent emissions from the summer of 1989 to the summer of 1990. The mean values for each analyte are discussed by analyte in Section 4.6.4.

4.6.3 Maximum Volatile Organic Compounds Concentrations

A summary of 24-hour maximum concentrations is presented in Table 4.6-3. Most of the compounds' maxima occurred during Phase 1, although many recurred in Phase 2. Maxima during Phases 3 and 4 were generally quite low by comparison. Phase 4 maximum concentrations were higher than those from Phase 3 for most compounds, reflecting the trend followed by the mean concentrations. The levels of the maximum values may be especially sensitive to the winter inversion conditions, which did not occur in Phase 3.

The extreme VOC cases, selected from IRA-F monitoring results, were chosen based on the relative maxima among all target VOCs. These extreme events were also selected based upon certain meteorological criteria which would contribute to development of elevated levels. The meteorological conditions which intensify VOC emissions and accumulation are warm temperatures (70 degrees Fahrenheit (°F) or warmer), light winds and stable atmospheric conditions. A dry ground surface is more conducive to VOC emissions than a moist surface. If a nighttime inversion develops, the VOC emissions are trapped in a fairly shallow surface layer, and ambient concentrations are increased. The results from the selected days were matched to the dispersion patterns for the corresponding 24-hour sampling periods to correlate the actual results with the theoretical dispersion. Two representative examples of elevated VOC days were selected for evaluation.

Table 4.6-3 24-Hour Maximum VOC Concentrations ($\mu\text{g}/\text{m}^3$) at Basin F, RIFS and IRA-F Sampling Locations

	ACET	C6H6	BCHPD	CCL4	111TCE	112TCE	CHCL3	CLC6H5	DCPD	11DCL	12DCL	DBCP	NNDMEA
Phase 1 (3/22/88 - 12/12/88)													
BF-1	47.73	6.89	17.98	3.89	72.54	ND*	18.51	0.45	4.58	ND	0.23	N/A	N/A
BF-2	55.53	10.83	39.46	6.68	53.40	ND	37.15	0.80	29.12	0.08	1.89	N/A	N/A
BF-2C	28.58	9.22	26.19	1.60	28.58	ND	31.14	0.52	8.30	ND	1.36	N/A	N/A
BF-3	81.65	5.20	2.69	4.00	62.88	ND	3.11	ND	6.04	ND	0.24	N/A	N/A
BF-4	112.12	6.52	12.25	5.61	67.00	1.12	18.03	0.39	3.74	ND	ND	N/A	N/A
BF-5	121.38	6.82	2.64	1.19	40.48	ND	5.65	0.05	2.15	ND	0.15	N/A	N/A
BF-6	41.93	5.74	0.50	1.17	71.11	ND	1.70	ND	0.41	ND	0.09	N/A	N/A
BF-7	151.22	6.47	0.13	1.41	22.06	ND	0.67	ND	0.14	ND	0.04	N/A	N/A
RIFS1	N/A	9.59	0.49	0.95	4.78	ND	1.33	0.12	3.77	ND	0.25	0.04	ND
Phase 2 - Stage 1 (12/13/88 - 2/15/89)													
BF-1	56.24	8.87	1.77	1.93	9.45	ND	3.24	0.06	3.36	ND	ND	N/A	N/A
BF-2	42.24	7.78	6.66	2.21	17.47	ND	16.41	0.10	2.48	ND	0.59	N/A	N/A
BF-2C	44.49	6.07	0.46	1.75	28.90	ND	1.57	ND	0.18	ND	ND	N/A	N/A
BF-3	30.04	6.83	0.85	2.52	11.48	ND	1.19	ND	1.27	ND	0.11	N/A	N/A
BF-4	54.75	8.97	1.51	1.30	15.74	ND	0.92	ND	1.37	ND	0.24	N/A	N/A
BF-5	22.34	4.71	7.27	1.59	8.55	ND	0.75	ND	0.60	ND	0.12	N/A	N/A
BF-6	24.5	8.57	0.37	2.25	8.04	ND	0.86	ND	ND	ND	0.10	N/A	N/A
BF-7	14.23	9.64	0.08	2.39	9.75	ND	0.90	0.11	0.17	ND	0.08	N/A	N/A
RIFS1	N/A	11.80	ND	8.59	6.38	ND	1.06	0.32	ND	ND	3.41	ND	ND
RIFS1D	N/A	14.20	ND	4.46	5.38	ND	0.65	0.06	ND	ND	1.09	ND	ND
RIFS2	N/A	10.90	0.74	9.76	4.65	ND	0.48	0.10	ND	ND	3.80	ND	ND
Phase 2 - Stage 2 (2/16/89 - 5/5/89)													
BF-1	24.39	4.08	0.91	1.13	12.51	ND	1.11	0.08	2.54	ND	0.10	N/A	N/A
BF-2	22.60	3.23	0.23	1.16	5.29	ND	0.71	0.08	0.35	ND	0.08	N/A	N/A
BF-2C	43.47	2.55	0.41	1.38	8.00	4.00	0.72	ND	ND	ND	ND	N/A	N/A
BF-3	22.49	4.14	0.12	1.09	5.16	ND	0.60	0.07	0.17	ND	0.10	N/A	N/A
BF-4	17.73	4.34	0.29	0.97	6.66	ND	0.48	ND	0.12	ND	0.06	N/A	N/A
BF-5	7.11	2.44	0.04	0.76	3.34	1.90	0.36	0.09	ND	ND	0.07	N/A	N/A
BF-6	6.29	2.60	ND	0.87	4.22	ND	0.44	0.09	ND	ND	ND	N/A	N/A
BF-7	16.22	3.10	0.04	0.99	8.54	ND	0.26	0.09	ND	ND	0.06	N/A	N/A
RIFS1	N/A**	6.72	ND	2.83	8.75	ND	0.30	0.17	ND	ND	0.21	ND	ND
RIFS1D	N/A	3.35	ND	0.80	1.66	ND	0.27	0.12	ND	ND	0.14	ND	ND
RIFS2	N/A	5.73	ND	1.24	2.64	ND	0.27	ND	ND	ND	0.34	ND	ND
Phase 3 (5/6/89 - 9/30/89)													
FC-1	N/A	2.43	ND	0.61	1.79	ND	0.33	0.07	ND	ND	0.04	0.28	ND
FC-2	N/A	2.72	ND	0.79	1.79	ND	0.69	0.07	ND	ND	0.08	ND	ND
FC-2D	N/A	2.55	ND	0.69	1.77	ND	0.76	0.11	ND	ND	0.10	ND	ND
BF-3/FC-3	N/A	2.78	ND	0.97	1.80	ND	0.30	0.05	ND	ND	0.10	ND	ND
BF-4/FC-4	N/A	3.00	ND	0.81	2.14	ND	0.33	0.05	ND	ND	0.09	ND	ND
BF-5	N/A	2.04	ND	0.77	1.29	ND	0.17	0.08	ND	ND	0.09	0.09	ND
FC-5	N/A	1.45	ND	0.94	1.41	ND	0.34	0.05	ND	ND	0.09	ND	ND
BF-7	N/A	2.10	ND	0.73	2.00	ND	0.16	0.07	ND	ND	0.04	0.05	ND
RIFS1	N/A	2.57	ND	0.55	2.14	ND	0.30	0.08	ND	ND	0.10	ND	ND
Phase 4 (10/1/89 - 9/30/90)													
FC-1	N/A	3.53	ND	1.43	3.89	ND	1.32	0.05	ND	ND	0.20	0.10	ND
FC-2	N/A	3.17	0.22	1.31	4.17	ND	2.23	0.05	ND	ND	0.25	ND	ND
FC-2D	N/A	3.16	0.21	1.13	4.33	ND	2.21	0.04	ND	ND	0.24	0.35	ND
FC-3	N/A	3.33	0.07	1.52	4.34	0.06	0.57	0.07	ND	0.05	0.22	0.10	0.12
FC-4	N/A	2.98	ND	1.64	4.60	ND	0.54	0.04	ND	ND	0.24	0.31	ND
FC-5	N/A	3.50	0.05	1.43	3.78	ND	1.18	0.04	ND	ND	0.23	ND	ND
	DMDS	ETC6H5	HCB	MEK	CH2CL2	MIBK	T12DCE	TCLEE	MEC6H5	TRCLE	12DMB	XYLEN	T-XYLENS
Phase 1 (3/22/88 - 12/12/88)													
BF-1	36.72	4.95	N/A**	8.48	54.80	0.19	ND*	16.02	35.55	1.47	N/A	N/A	25.94
BF-2	24.06	8.91	N/A	8.14	55.34	ND	ND	23.17	90.10	0.78	N/A	N/A	49.91
BF-2C	23.69	4.95	N/A	4.60	72.36	ND	ND	9.14	158.04	1.06	N/A	N/A	17.20
BF-3	4.97	3.98	N/A	5.27	57.64	ND	ND	2.30	49.41	1.00	N/A	N/A	10.51
BF-4	8.07	3.39	N/A	5.22	58.14	ND	ND	3.40	49.91	1.81	N/A	N/A	10.39
BF-5	3.95	2.48	N/A	6.46	50.81	ND	ND	3.32	14.49	1.00	N/A	N/A	10.52
BF-6	0.28	1.79	N/A	5.74	179.09	ND	ND	2.61	51.49	0.62	N/A	N/A	12.90
BF-7	0.10	2.38	N/A	4.32	30.26	ND	ND	2.66	19.61	0.90	N/A	N/A	11.56
RIFS1	0.11	3.00	N/A	N/A	13.70	0.51	ND	2.80	16.50	0.26	4.56	6.38	9.22
Phase 2 - Stage 1 (12/13/88 - 2/15/89)													
BF-1	ND	4.38	ND	14.78	23.52	ND	ND	3.19	13.32	0.57	N/A	N/A	17.26
BF-2	0.08	4.2	ND	14.2	15.73	ND	ND	4.48	11.43	0.34	N/A	N/A	15.77
BF-2C	ND	2.25	ND	9.56	19.59	ND	ND	3.49	8.55	0.22	N/A	N/A	11.22
BF-3	ND	3.75	ND	13.24	23.71	ND	ND	2.83	11.14	0.34	N/A	N/A	15.57
BF-4	ND	8.97	ND	13.22	19.77	ND	ND	5.52	19.52	0.65	N/A	N/A	28.28
BF-5	ND	1.99	ND	10.54	6.51	ND	ND	2.58	8.42	0.17	N/A	N/A	10.39
BF-6	ND	2.5	ND	10.11	2.74	ND	ND	2.33	6.95	0.47	N/A	N/A	7.68
BF-7	ND	2.93	ND	8.45	7.56	ND	0.05	2.57	7.8	0.44	N/A	N/A	9.29
RIFS1	ND	6.16	N/A	N/A	32.50	ND	ND	3.44	23.90	0.61	6.15	12.30	15.72
RIFS1D	ND	5.69	N/A	N/A	22.90	ND	ND	3.44	30.80	0.32	8.03	14.40	22.43
RIFS2	ND	5.32	N/A	N/A	17.00	ND	ND	2.99	29.60	0.31	6.98	12.60	19.58
Phase 2 - Stage 2 (2/16/89 - 5/5/89)													
BF-1	0.05	3.62	ND	8.60	28.85	ND	ND	24.02	6.93	40.43	N/A	N/A	13.54
BF-2	ND	1.18	ND	7.64	72.80	ND	ND	2.14	6.22	2.86	N/A	N/A	6.76
BF-2C	ND	1.50	ND	10.25	59.83	ND	ND	1.98	8.57	0.47	N/A	N/A	8.50
BF-3	ND	1.28	ND	7.17	433.69	ND	ND	2.10	7.49	0.21	N/A	N/A	7.10
BF-4	ND	1.72	ND	4.83	14.06	ND	ND	2.04	8.38	0.55	N/A	N/A	8.92
BF-5	ND	1.11	ND	5.54	5.18	ND	ND	1.51	5.67	0.15	N/A	N/A	6.31
BF-6	ND	0.94	ND	7.16	5.74	ND	ND	1.44	5.22	0.11	N/A	N/A	5.72
BF-7	ND	1.11	ND	8.85	6.30	ND	ND	2.27	6.77	0.07	N/A	N/A	6.25
RIFS1	ND	2.28	N/A	N/A	20.50	ND	ND	3.82	21.00	0.21	3.05	4.63	7.39
RIFS1D	ND	1.07	N/A	N/A	2.75	ND	ND	1.67	10.40	0.10	1.51	5.56	7.01
RIFS2	ND	2.06	N/A	N/A	4.91	ND	ND	2.59	16.50	0.07	2.10	6.41	8.51
Phase 3 (5/6/89 - 9/30/89)													
FC-1	ND	1.04	N/A	N/A	3.43	0.14	ND	1.69	3.24	1.52	1.56	3.06	4.62
FC-2	ND	3.99	N/A	N/A	3.26	0.18	ND	1.35	2.97	0.12	1.76	3.31	5.07
FC-2D	ND	1.02	N/A	N/A	0.65	0.09	ND	1.33	4.40	0.15	1.45	3.20	4.27
BF-3/FC-3	ND	1.19	N/A	N/A	4.24	0.20	ND	1.63	2.87	0.09	1.70	3.57	5.27
BF-4/FC-4	ND	1.25	N/A	N/A	4.06	0.21	ND	2.50	5.00	0.11	1.81	3.48	5.29
BF-5	ND	0.75	N/A	N/A	0.44	ND	ND	1.16	3.25	0.19	1.19	2.61	3.80
FC-5	ND	1.05	N/A	N/A	6.77	0.15	ND	1.44	3.62	0.93	1.31	2.51	3.82
BF-7	ND	0.61	N/A	N/A	0.74	0.09	ND	1.60	2.93	0.07	0.78	1.97	2.70
RIFS1	ND	0.87	N/A	N/A	0.92	ND	ND	1.40	3.54	0.10	1.22	3.19	4.31
Phase 4 (10/1/89 - 9/30/90)													
FC-1	ND	2.27	N/A	N/A	2.53	0.63	ND	2.38	10.60	0.45	2.69	7.07	8.84
FC-2	ND	2.67	N/A	N/A	1.98	0.88	ND	6.34	10.80	0.23	2.81	6.97	9.06
FC-2D	ND	2.62	N/A	N/A	1.57	1.13	ND	2.59	10.70	0.26	2.87	7.04	9.50
FC-3	ND	2.84	N/A	N/A	1.60	0.84	0.06	5.98	10.90	0.30	3.19	7.07	9.37
FC-4	ND	3.01	N/A	N/A	2.03	1.13	ND	3.51	9.93	0.30	3.08	6.62	8.79
FC-5	ND	2.24	N/A	N/A	1.45	0.75	ND	2.91	10.60	0.50	2.34	7.09	8.99

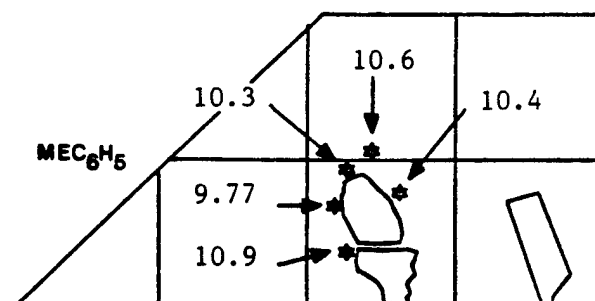
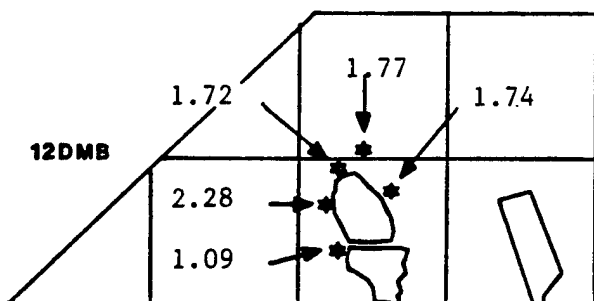
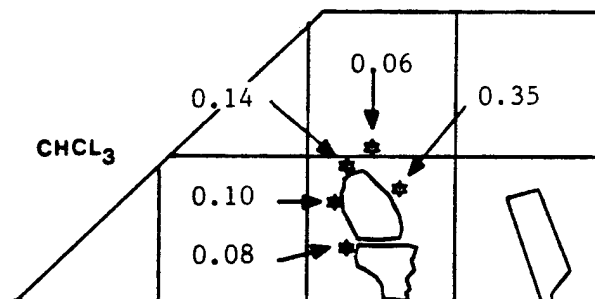
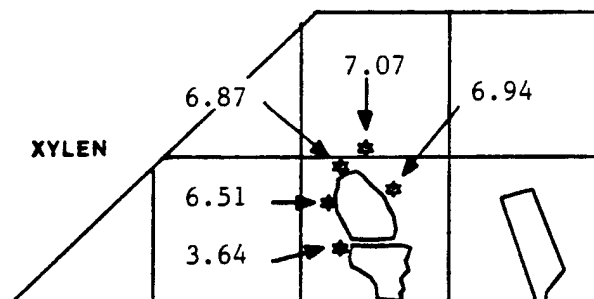
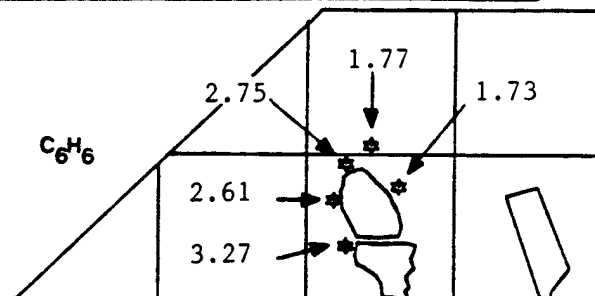
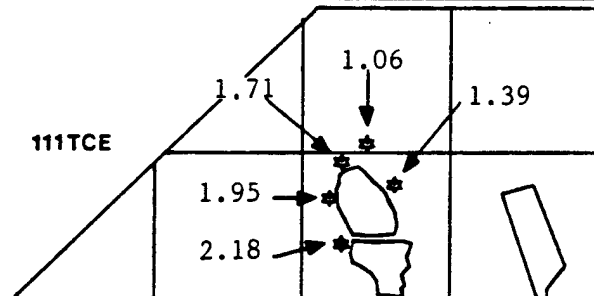
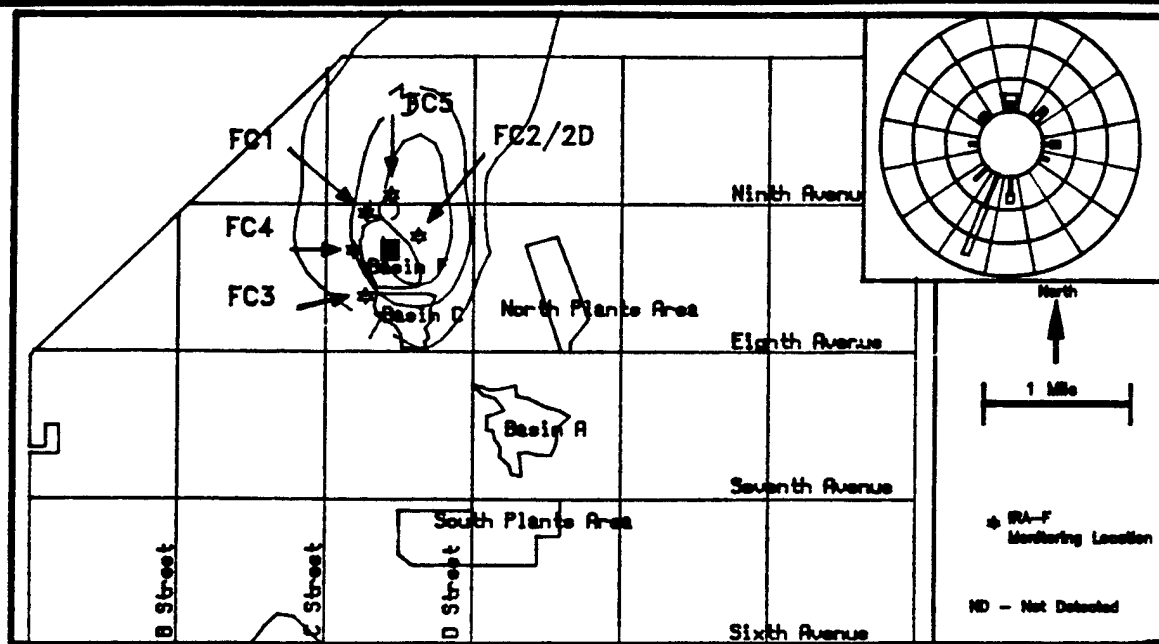
4.6.3.1 Volatile Organic Compounds High Event: August 3, 1990

August 3, 1990, exhibited higher than average VOC concentrations. Figure 4.6-1 shows the X/Q dispersion pattern, the corresponding wind rose and the reported IRA-F VOC concentrations for the sample period (1200 MST on August 2 through 1200 MST on August 3, 1990). Temperatures were in the 70s with a high of 80°F and an overnight low of 56°F. Winds were moderate and primarily from the south-southwest, with a few short periods of south-southeasterly winds. The most recent precipitation was approximately 1 inch on July 29, 1990, but the ground was dry. Atmospheric stability was neutral as a result of the moderate wind speeds. A late evening inversion developed after wind speeds decreased.

High values were detected for 1,1,1-Trichloroethane ($2.18 \mu\text{g}/\text{m}^3$), benzene ($3.27 \mu\text{g}/\text{m}^3$), and toluene ($10.9 \mu\text{g}/\text{m}^3$), at FC-3 upwind of Basin F. The high values may have been due to the Basin A Neck excavation which was in progress upwind of these areas. A less consistent pattern can be seen with xylene, $7.07 \mu\text{g}/\text{m}^3$ at FC-5; 1,2-dimethyl benzene $2.28 \mu\text{g}/\text{m}^3$ at FC-4; and chloroform, $0.35 \mu\text{g}/\text{m}^3$ at FC-2. These sites were downwind from the Basin F area, but a lack of consistent pattern among these analytes indicates that Basin F was not a likely source for these VOCs. Local roadways may have had a minor impact on sites FC-5 and FC-1. The Basin A Neck excavation work may have also contributed to the concentrations of these contaminants during the early hours of the sample period while south-southeast winds were present.

4.6.3.2 Volatile Organic Compounds High Event: September 20, 1990

Recorded concentrations of some VOCs sampled at IRA-F sites were elevated on this day. Figure 4.6-2 shows the X/Q dispersion pattern, the corresponding wind rose, and the reported IRA-F VOC concentrations for the day (1200 MST on September 19 through 1200 MST on September 20, 1990). Temperatures were in the 60s with a high of 73°F and a low of 48°F. Winds were light to moderate and northerly during the first third of the sample period, then southerly for the remainder of the time. The ground surface was dry, but 0.81 inches of precipitation had fallen during the previous day. The neutral atmospheric stability provided good conditions for VOC emissions. A relatively even pattern of VOC concentrations can be seen for



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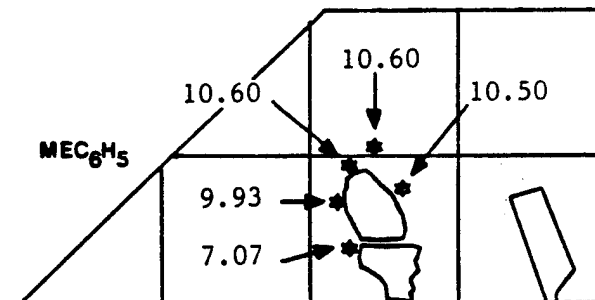
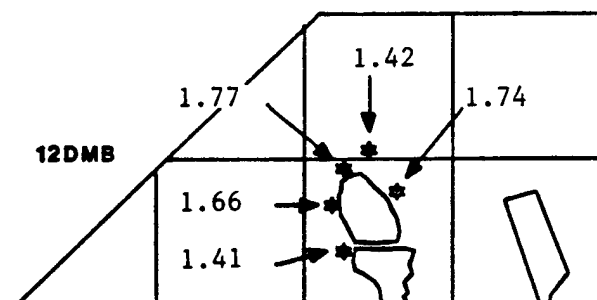
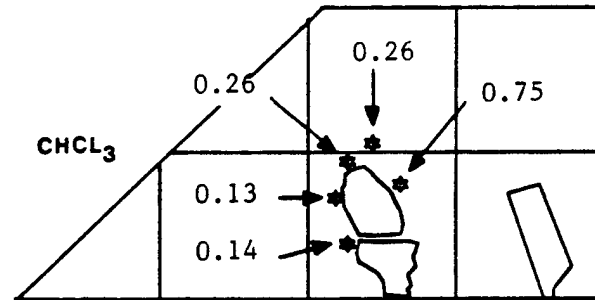
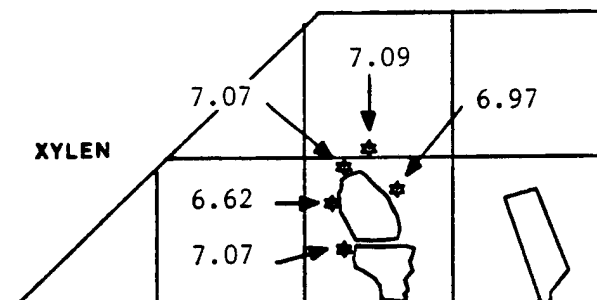
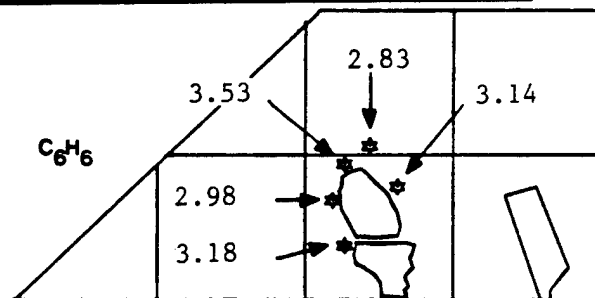
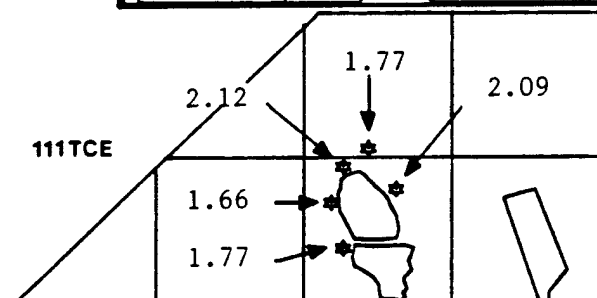
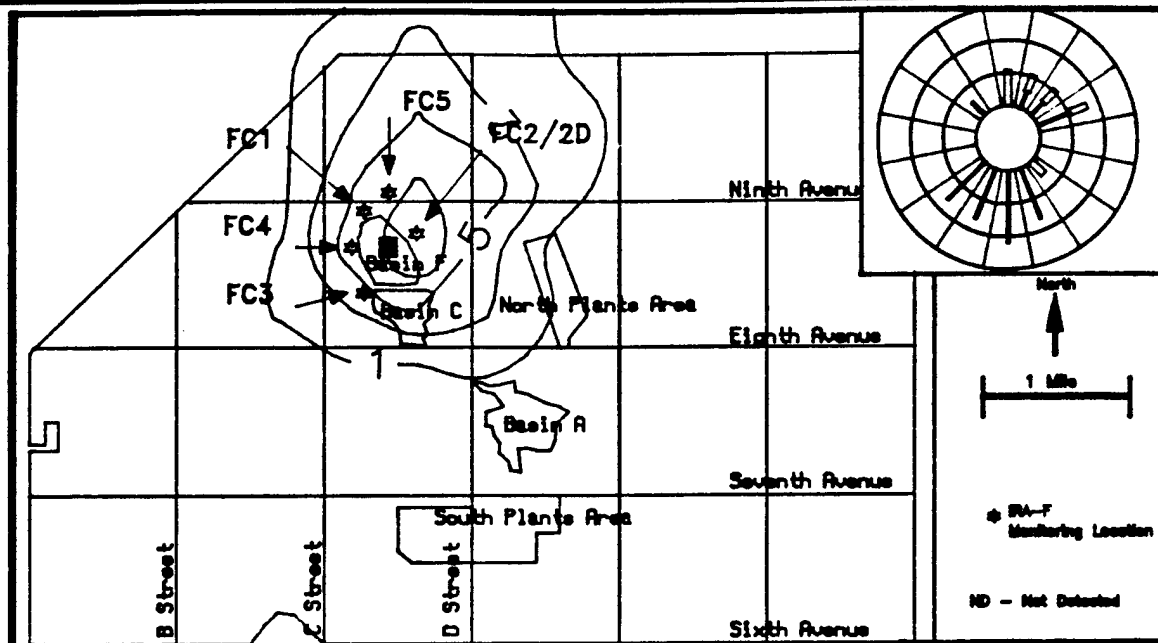
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Figure 4.6-1

**X/Q Dispersion Pattern, Wind Rose and VOC
Concentrations for August 3, 1990**

($\mu\text{g}/\text{m}^3$)



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Figure 4.6-2

**X/Q Dispersion Pattern, Wind Rose and VOC
Concentrations for September 20, 1990**

($\mu\text{g}/\text{m}^3$)

each of the target analytes, suggesting the Basin F area was not a predominant source of VOCs. It must be noted that site FC-4, which was not downwind to either of the prevailing wind directions, recorded slightly lower concentrations of target analytes than the sites that had been downwind. Sites FC-1 and FC-5, may have received some minor impact from traffic on the nearby roadway. The compounds 1,1,1-trichloroethane, 1,2-dimethyl benzene and benzene had the highest values at FC-1, with values of $2.12 \mu\text{g}/\text{m}^3$, $1.77 \mu\text{g}/\text{m}^3$ and $3.53 \mu\text{g}/\text{m}^3$, respectively. Other compounds which produced elevated results were xylene, $7.09 \mu\text{g}/\text{m}^3$ at FC-5; chloroform, $0.75 \mu\text{g}/\text{m}^3$ at FC-2; and toluene, $10.60 \mu\text{g}/\text{m}^3$ at sites FC-1 and FC-5.

4.6.4 Analysis of Results for Target Volatile Organic Compounds

This section presents the results of the Basin F, IRA-F, and the odor sampling program efforts in a graphical format for ease of interpretation and clarity of comparative results. These compounds were also sampled under the RI program in 1987, prior to the Basin F remedial activity, and under the CMP which has run concurrently with the Basin F programs. However, the CMP has had a more limited VOC sampling effort. Results of other programs are provided where necessary to supplement the Basin F, odor, and IRA-F program results.

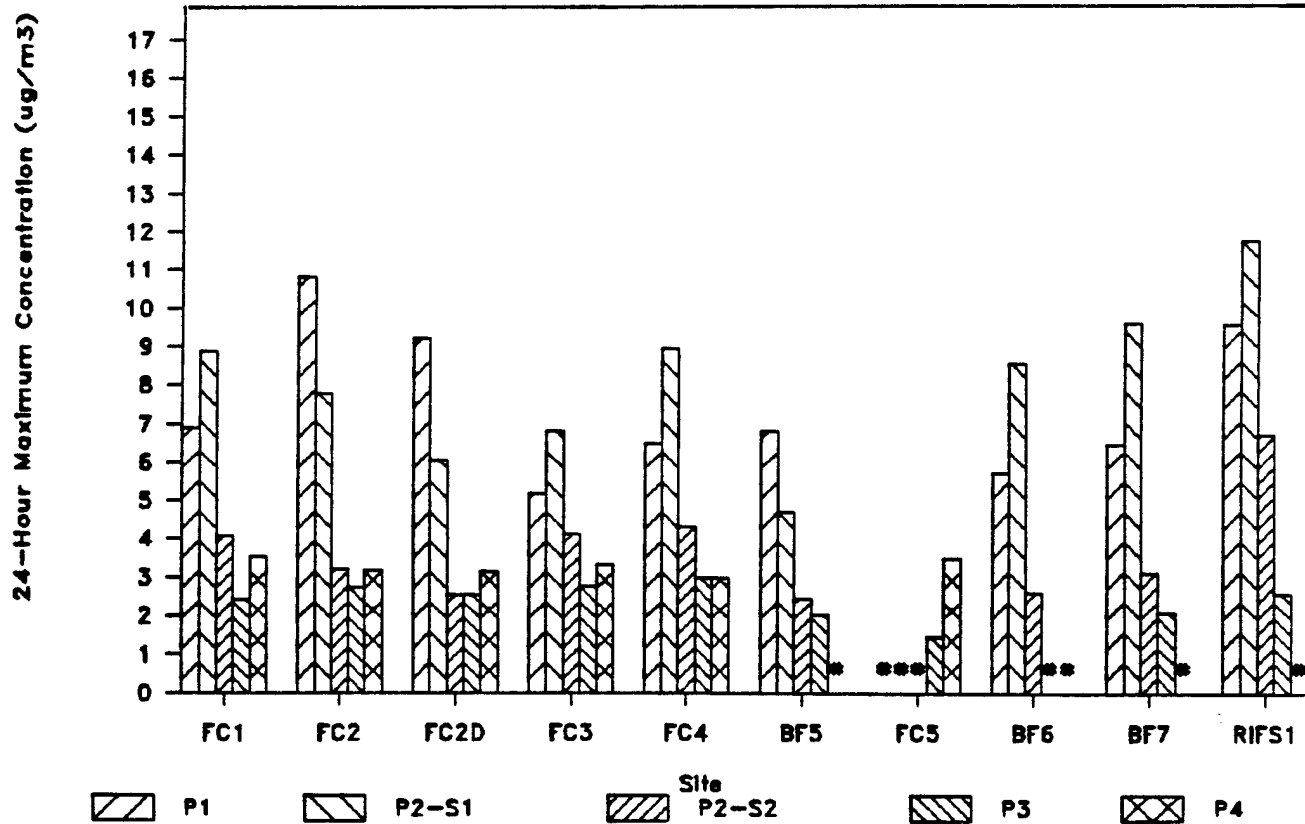
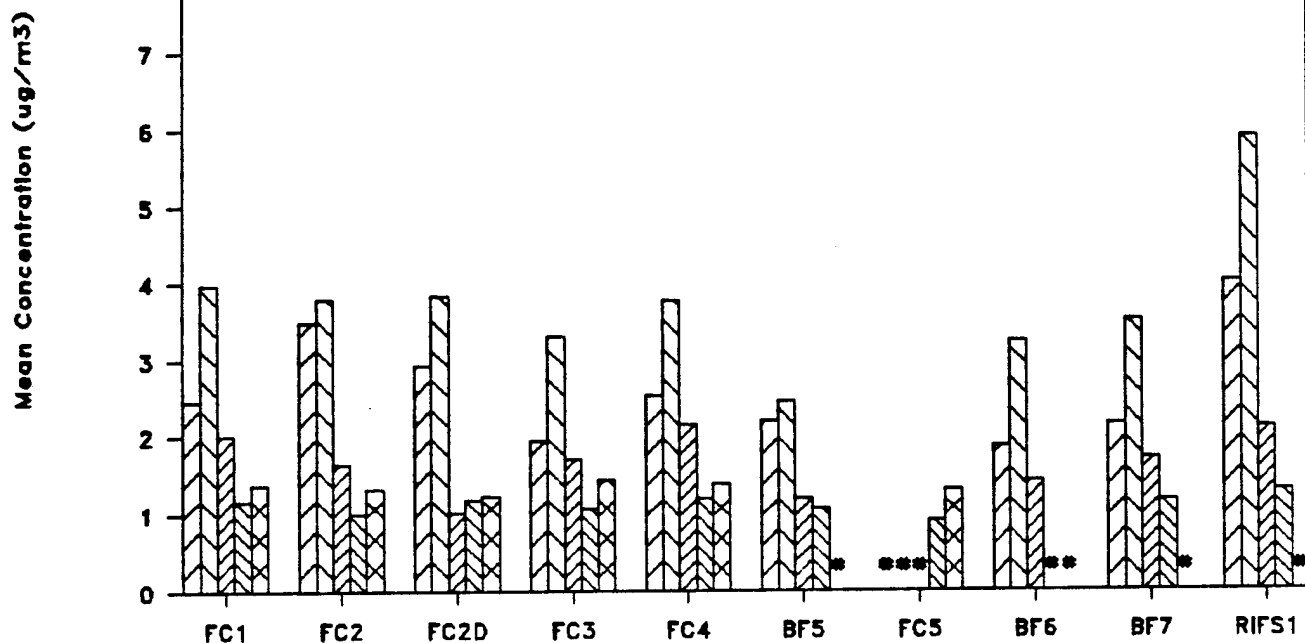
The thrust of CMP VOC monitoring was to establish an area-wide baseline database, and to identify and measure potential RMA interior sources. The sampling schedule used included both seasonal and high event monitoring at times when VOCs were likely to be present in the highest concentrations. Because the best sampling conditions included the presence of very light winds, preferably 5 mph or less, and because light winds were normally highly variable in direction, the CMP sampling strategy was to surround a potential source, and thus sample any air escaping the area regardless of wind flow direction. The CMP conducted VOC sampling in the vicinities of South Plants, Basin F, the South Plants subdrain area, Basin A and Basin A Neck, as well as at CMP sites around the RMA boundary. A comparison of CMP results to those collected more systematically around Basin F can clarify the nature of sources and impacts for each of the target VOCs.

In this section all VOC target analytes which have exhibited important patterns of ambient concentration are discussed. Analytes which have generally shown nondetections during these efforts are not discussed in detail, but are listed in the final subsection (4.6.4.17) as a summary. In each of the following subsections, the patterns of mean and extreme values for each analyte are presented in a graphical format and provide an easy review and interpretation of the results.

4.6.4.1 Benzene

Benzene was a target analyte for all sampling programs. During the RI program, benzene was not detected in any of the seven samples. Results of benzene sampling around Basin F are presented in Figure 4.6-3, including both the mean and maximum values by site and by phase. Overall, the highest average benzene concentration occurred during Phase 2, Stage 1. During Phase 1 average concentrations were slightly higher around Basin F than at the remote sites. The one exception was at RIFS1, which was near the Arsenal boundary and an adjacent highway and rail route, and was likely to have been impacted by nearby traffic and the metropolitan Denver emissions. During Phase 2, Stage 1, the highest average benzene levels continued to be at site RIFS1. This was confirmed by even higher averages at the collocated site RIFS1D ($7.32 \mu\text{g}/\text{m}^3$), and the second-highest average at RIFS2 ($4.95 \mu\text{g}/\text{m}^3$), which was located off-post, approximately 1/2 mile north of the RMA boundary. The extreme maximum benzene levels were detected at the RIFS sites during this period. In Phase 2, Stage 2, benzene levels dropped significantly. By Phase 4, all sites reported average levels in the 1.2 to $1.5 \mu\text{g}/\text{m}^3$ range. The 24-hour maximum benzene levels during Phase 4 were all in the range of 3.0 to $3.5 \mu\text{g}/\text{m}^3$.

On a predicted high event day (December 19, 1989), the CMP reported maximum post-remedial levels of many target VOCs at site AQ5, which is near the RMA south entrance at Havana Street. The wind pattern showed prevailing flow from the Denver metropolitan area, and measured levels reflected urban sources. Benzene was measured at $7.5 \mu\text{g}/\text{m}^3$ on that day, a level well above the maxima reported at former Basin F sites during Phase 4.



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Figure 4.6-3

Mean and Maximum Concentrations for Benzene
by Site, by Phase

Not an Analyte This Phase

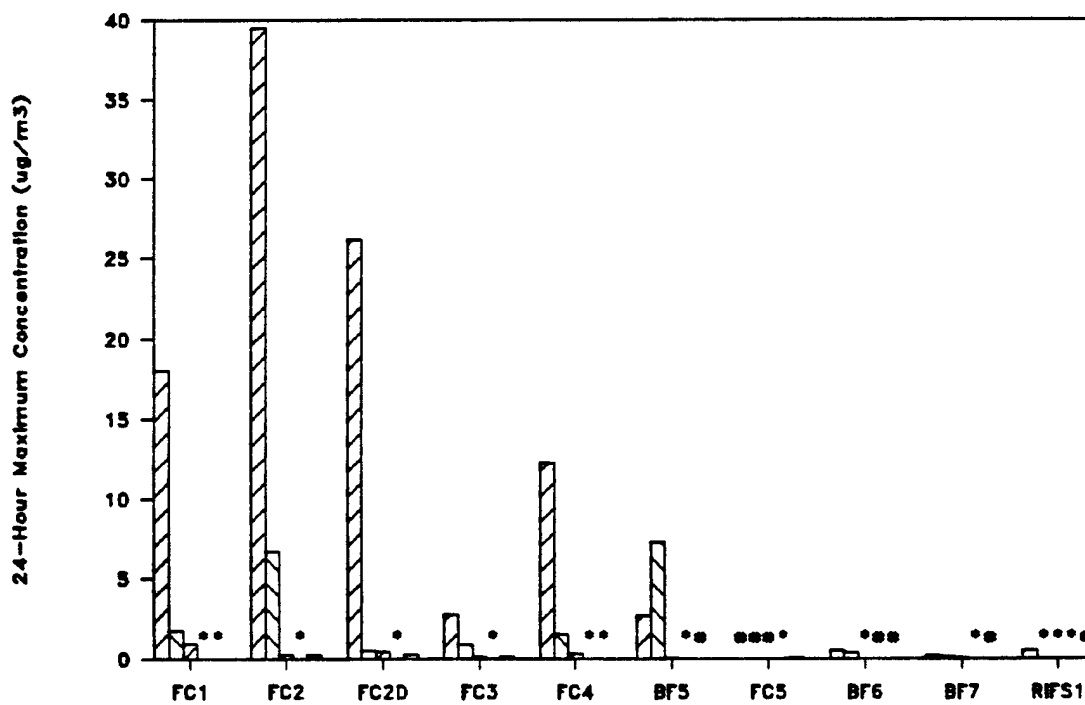
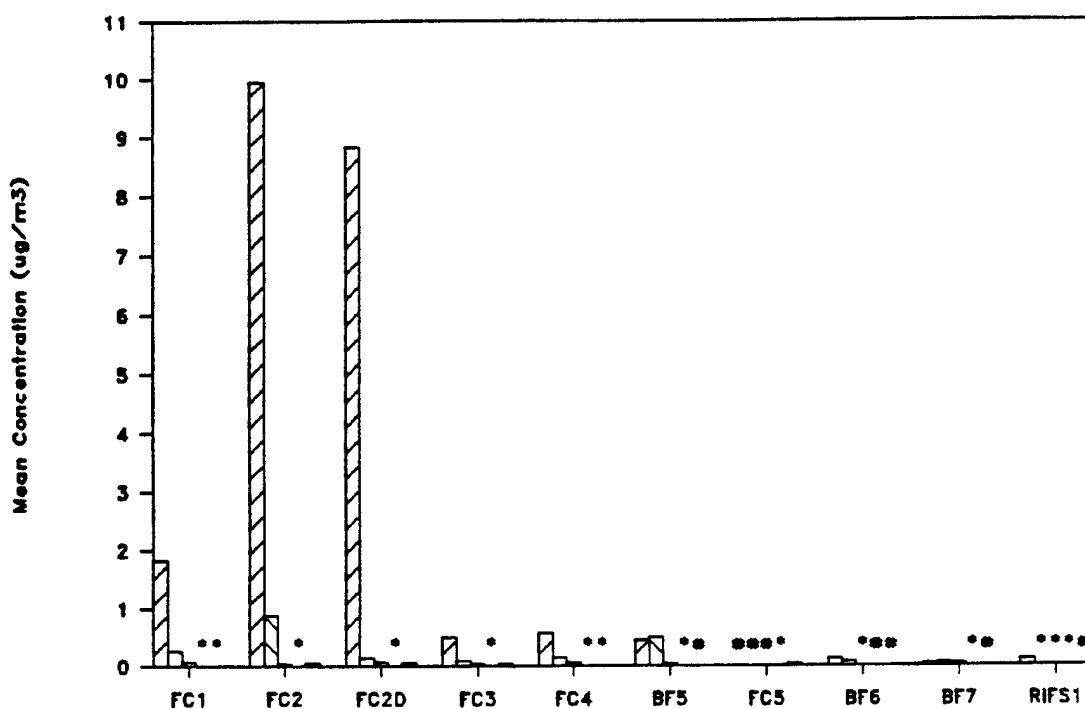
The pattern indicates that Basin F may have been a source of benzene during Phase 1, but sources in metropolitan Denver may have been even greater. The source of benzene at Basin F could be attributed to engine emissions from heavy equipment used to handle wastes and haul dirt. By Phase 4, however, there was no evidence of a Basin F source of benzene, and based on the CMP high events, there was clear evidence of an urban source for measured benzene levels.

4.6.4.2 Bicycloheptadiene

Bicycloheptadiene (BCHPD) is a pollutant that is not commonly found in urban airsheds, nor was there evidence of a nearby off RMA source of this compound. Figure 4.6-4 provides the mean and extreme BCHPD levels for the Basin F monitoring programs. It is clear that BF-2 had the highest concentrations of this compound during Phase 1, and those extremes were confirmed by the results of the collocated site BF-2C. Site BF-2 was in a location most likely to be impacted by Basin F operations since prevailing winds were from the south or south-southwest. Although much lower, the highest average concentration of BCHPD during Phase 2, Stage 1 was also at BF-2. After Phase 2, Stage 1, almost all measurements of this analyte were at or slightly above the LCRL.

During Phase 1, the maximum BCHPD concentrations were at sites immediately adjacent to and downwind of Basin F. At BF-3, which was a perimeter site upwind in the prevailing direction, the maximum concentration was one-tenth or less of the maximum concentrations recorded downwind. The results for BF-5 and BF-7 should be compared to assess the effect of the atmospheric dispersion pattern on the concentrations of Basin F emissions. For both the mean and extreme concentrations, the BF-7 data were an order of magnitude less than the BF-5 and other perimeter site data.

The sampling results for BCHPD were particularly important in determining source strength and atmospheric dispersion of compounds emitted from Basin F and the remedial activity. A spatial depiction of both the mean and maximum concentrations for Phase 1 and for Phase 2, Stage 1 is provided in Figure 4.6-5, along with isopleths of relative concentrations entered based upon



P1
 P2-S1
 P2-S2
 P3
 P4

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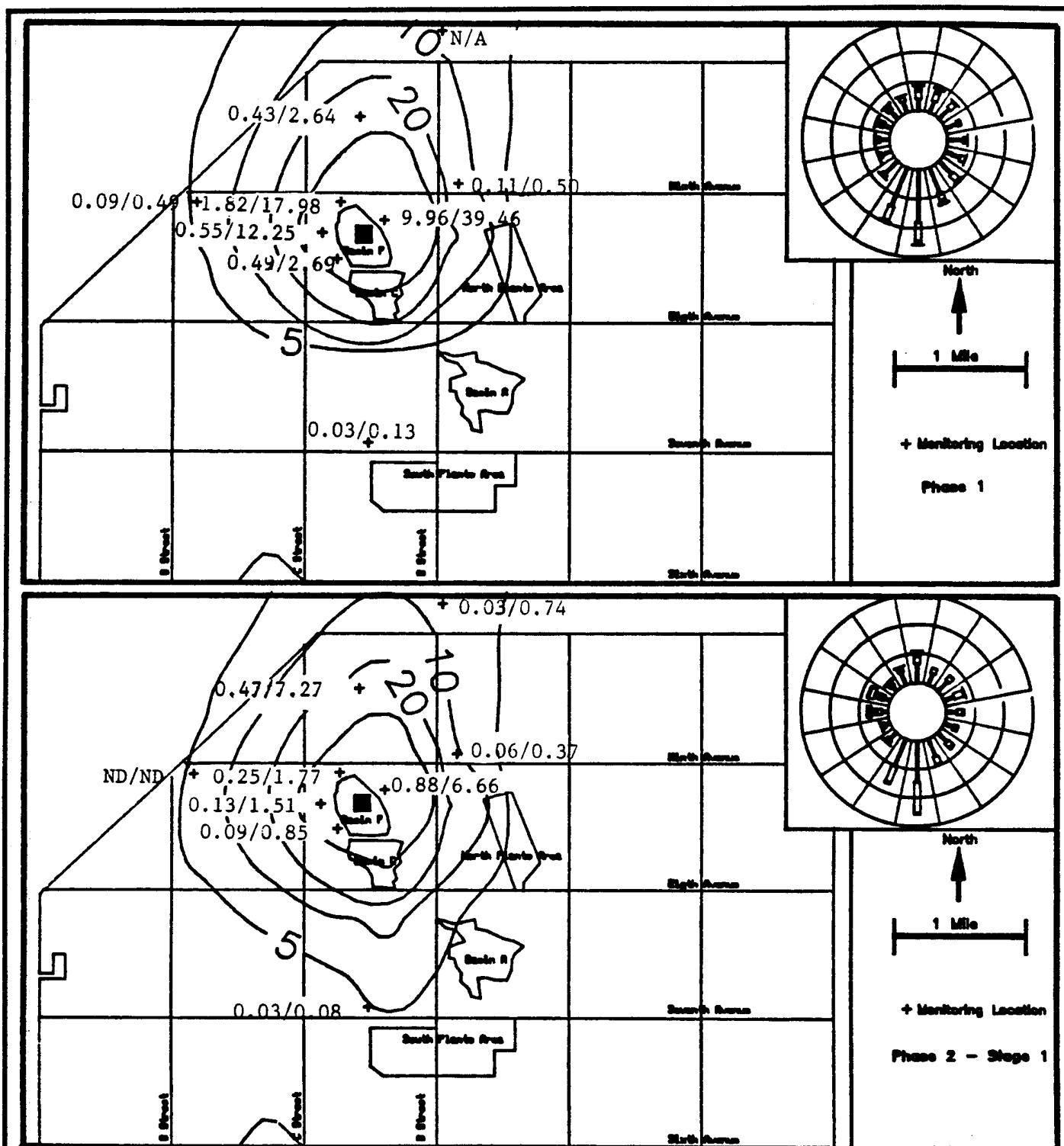
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Figure 4.6-4

Mean and Maximum Concentrations for
 Bicycloheptadiene by Site, by Phase

* Not Detected

Not an Analyte This Phase



Source: Basin F

Mean/Maximum

ND - Not Detected

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Figure 4.6-5

Mean and Maximum Concentrations for
Bicycloheptadiene during Phase 1 and Phase 2,
Stage 1
($\mu\text{g}/\text{m}^3$)

known meteorological dispersion conditions. During Phase 1, a source at Basin F (regardless of source strength) would have had its concentration diluted approximately 100-fold by the time those emissions were advected to the RMA boundary. This dilution was confirmed by the BF-2 average of $9.96 \mu\text{g}/\text{m}^3$ and the RIFS1 average of $0.09 \mu\text{g}/\text{m}^3$ during Phase 1. These patterns can and should be used elsewhere to estimate or interpret ambient concentrations of compounds emitted from Basin F.

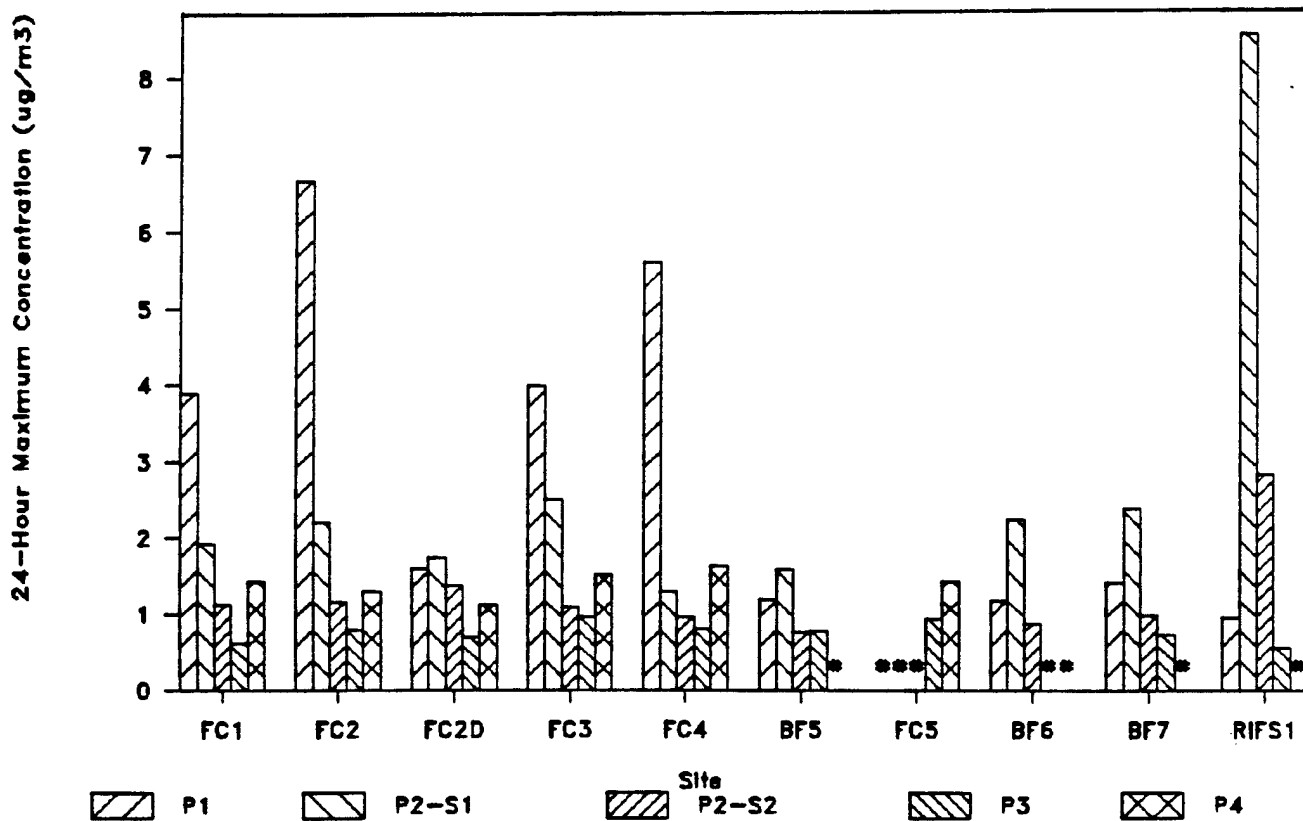
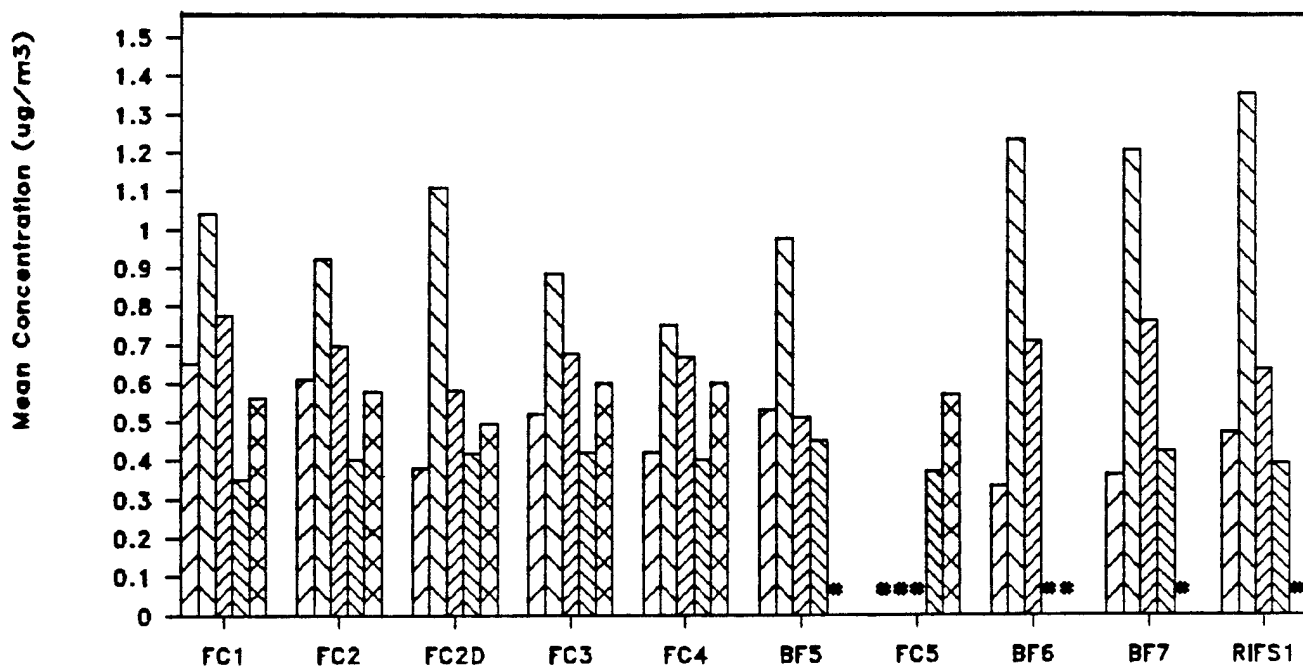
During two separate CMP high event monitoring efforts during the summer of 1990, BCHPD was detected at two sites north of the South Plants complex. The maximum value was $1.08 \mu\text{g}/\text{m}^3$, substantially above the maxima reported around the former Basin F during Phases 3 and 4. Although the number of detections was relatively small, the CMP results indicated that the South Plants complex or a nearby area was a source of BCHPD during high event conditions.

Bicycloheptadiene was clearly emitted from Basin F, but concentrations decreased significantly during Phase 3 and Phase 4. The recurrence of valid BCHPD measurements in Phase 4, although very low, should give some cause for concern that there may be additional emissions from the former Basin F waste pile or floor cap. The compound BCHPD could serve as an indicator compound for emissions from the former Basin F.

4.6.4.3 Carbon Tetrachloride

Carbon tetrachloride (CCL_4) was included on all VOC target lists. During the RI program, it was not detected in any of the VOC samples. The Basin F sampling programs, however, showed consistent detections of this analyte. The mean and extreme CCL_4 results are shown graphically in Figure 4.6-6.

During Phase 1 the sites BF-1 and BF-2 which were on the downwind edge of Basin F showed slightly higher average levels than did other sites. The relative pattern of average values was clearly not similar to the patterns exhibited by BCHPD. The maximum values of CCL_4 indicated that Basin F was a likely source during some events. During Phase 2, Stage 1, however, the



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Figure 4.6-6

Mean and Maximum Concentrations for
Carbon Tetrachloride by Site, by Phase

Not an Analyte This Phase

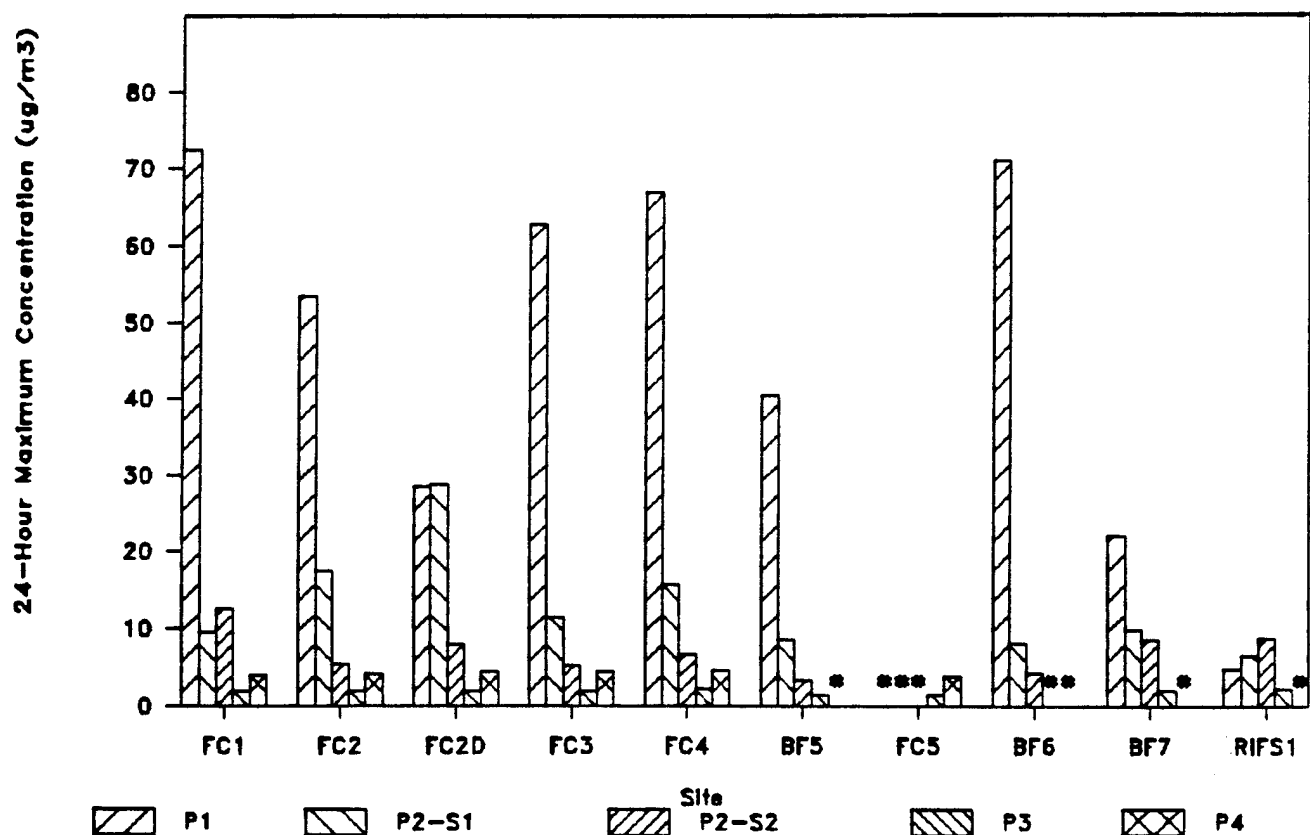
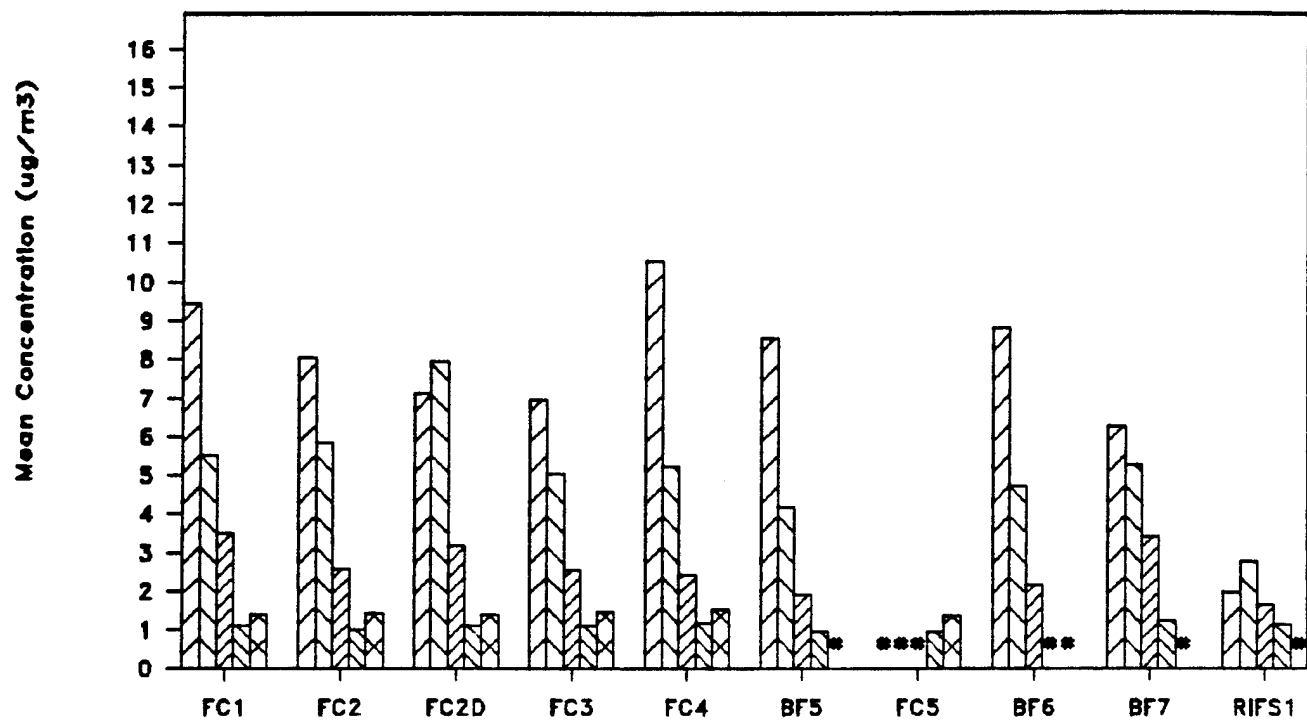
maximum levels were detected at the RIFS sites, implying that there was also a strong off-site source. During Phases 3 and 4, the CCL_4 patterns stabilized and showed no evidence of a source at the former Basin F. During the December 1989 CMP VOC high event, CCL_4 levels at AQ5 on the southern RMA boundary reached $1.17 \mu\text{g}/\text{m}^3$, a level that was roughly comparable to Phase 4 maxima at the former Basin F sites. Average CCL_4 levels at other RMA boundary sites were also comparable to the data from Basin F sites.

Based on these results, it is possible that Basin F may have been a minor source of CCL_4 during remedial activity, possibly due to several sporadic emissions. It is also possible, that there was an off-site source that contributed to the relatively high values at the RIFS sites. The former Basin F was not a likely source of CCL_4 during Phases 3 and 4.

4.6.4.4 1,1,1-Trichloroethane

The analyte 1,1,1-trichloroethane (111TCE) was not detected during the RI program, but was detected throughout the Basin F sampling programs. Results for this analyte are illustrated in Figure 4.6-7. During Phase 1, the levels of 111TCE were extremely high, with estimated maxima ranging from $22 \mu\text{g}/\text{m}^3$ to $73 \mu\text{g}/\text{m}^3$. At these levels, the laboratory's analytical accuracy became very uncertain, and it was not possible to draw firm conclusions from the data patterns. Both the average and maximum levels continued to decrease through Phase 2, with steady and consistent levels reported in Phases 3 and 4. The Phase 4 data showed an average level of about $1.4 \mu\text{g}/\text{m}^3$ at all sites, with individual maximum values around $4 \mu\text{g}/\text{m}^3$. During Phase 4, CMP results from RMA boundary sites showed slightly higher average and maximum levels. Concentrations at the southern boundary site, AQ5, were higher than at other sites. Curiously, the CMP Phase 4 levels tended to be above those of the previous 2 years of sampling, but the cause could not be determined.

Although Basin F activities were a likely source of 111TCE during Phases 1 and 2, that source was not evident during Phases 3 and 4. The fact that concentrations increased somewhat from Phases 3 to 4 may have resulted from the inclusion of a poor dispersion winter situation in



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Figure 4.6-7

Mean and Maximum Concentrations for
1,1,1-Trichloroethane by Site, by Phase

Not an Analyte This Phase

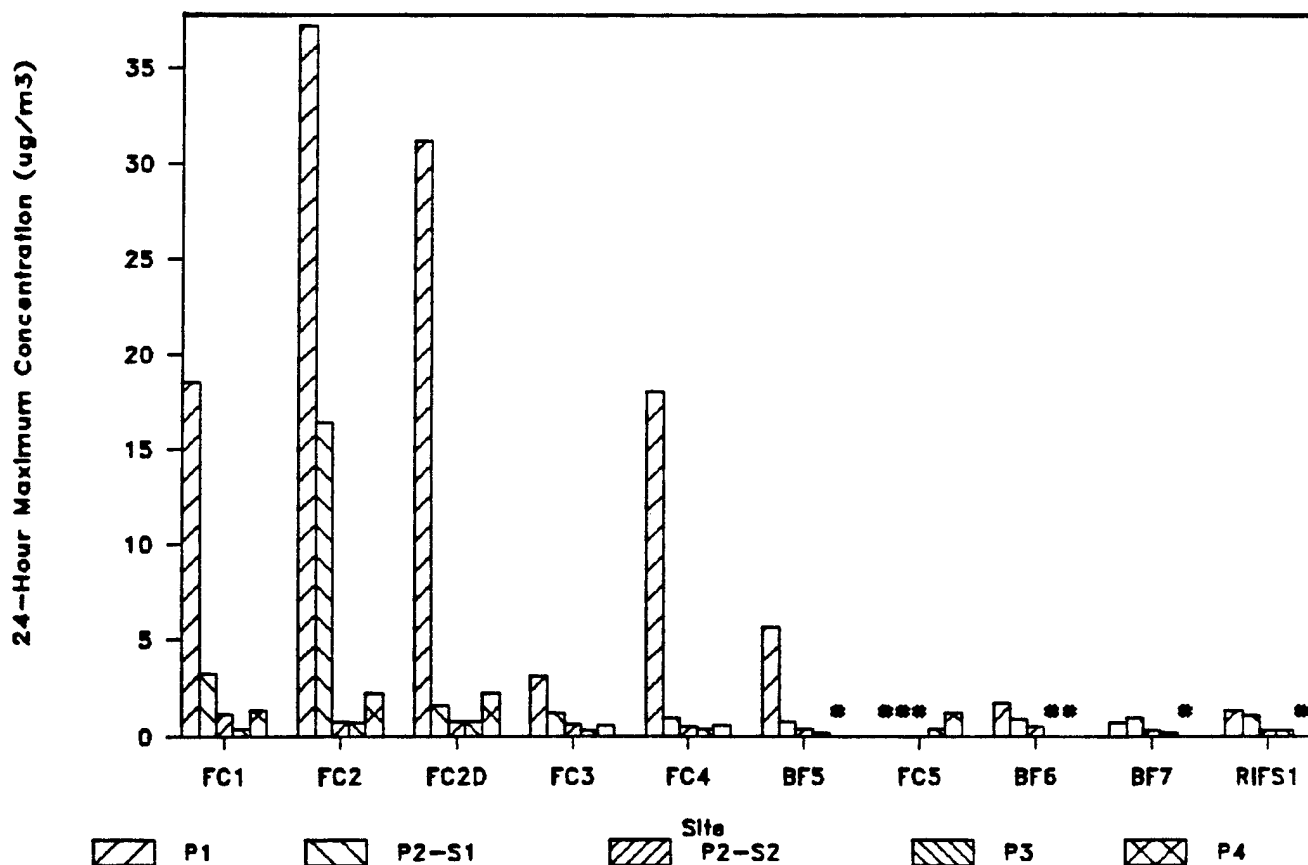
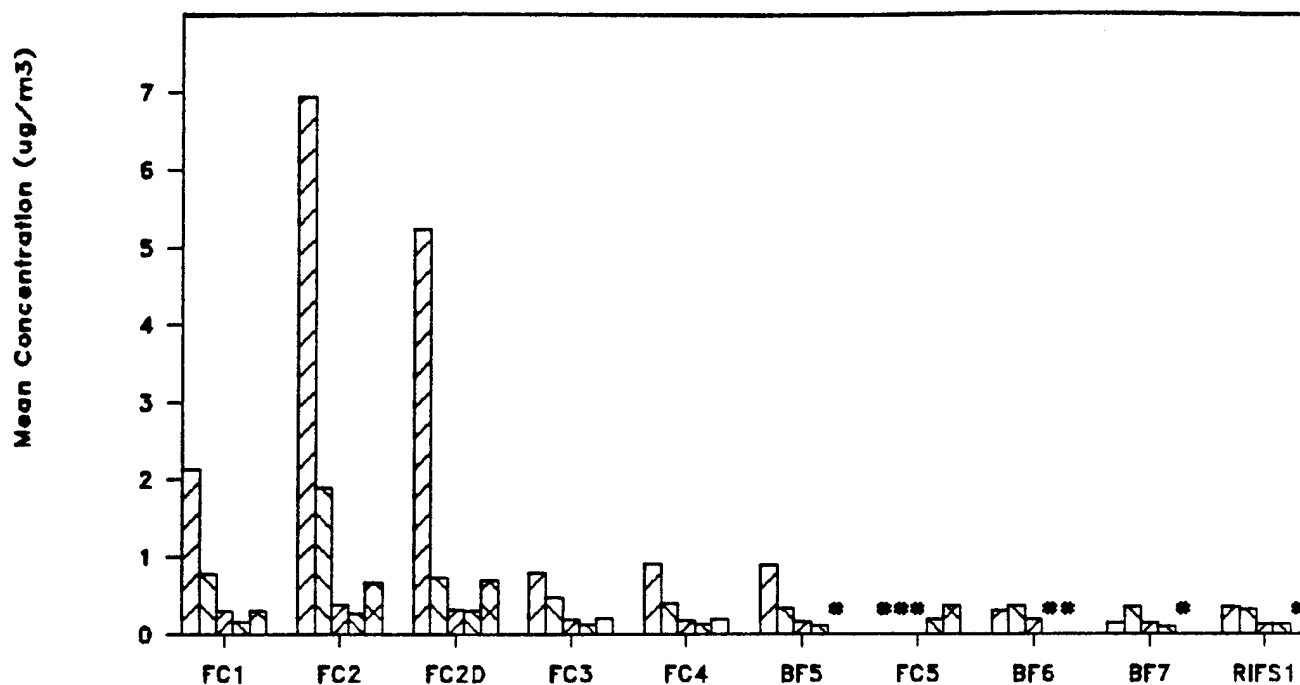
Phase 4, and in the inclusion of only summertime conditions into Phase 3. Fall and winter inversions in the Denver metropolitan area are known to worsen pollution conditions. The Denver urban sources were the likely cause of the higher 111TCE concentrations measured at RMA in the Phases 3 and 4.

4.6.4.5 Chloroform

Chloroform (CHCl_3) has also been a target analyte for each of the ambient air monitoring programs at RMA. During the RI program, chloroform was detected as a target VOC in one sample (at $30 \mu\text{g}/\text{m}^3$), that was taken essentially downwind of Basin F. The RI analyses were much less sensitive than those of subsequent programs, and it is likely that chloroform was present at concentrations which would have been detected with the lower detection limits available during the IRA-F program.

As Figure 4.6-8 shows, chloroform concentrations were substantially higher during Phase 1 than in the subsequent phases, and the highest concentrations were measured at the downwind sites BF-1 and BF-2. The reported maximum values must be used with a great deal of caution, because the estimated concentrations at those levels are very uncertain. As the intrusive activity ceased at the end of Phase 1, the chloroform levels dropped markedly. Sites BF-1 and BF-2 still reported the highest concentrations in both stages of Phase 2, but overall the levels had decreased.

It is important to note that through the remainder of Phases 2, 3, and 4, the highest average chloroform levels occurred at FC-2/BF-2, with a less distinct secondary maximum at FC-1/BF-1. This pattern indicates that Basin F continued to act as a source of chloroform throughout all phases, though the level of emissions was less than was indicated by the Phase 1 data. The collocated data at FC-2D in Phases 3 and 4 established the presence of a maximum impact downwind of former Basin F, which was confirmed by the secondary maxima at FC-1 and FC-5.



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Figure 4.6-8

Mean and Maximum Concentrations for
Chloroform by Site, by Phase

Not an Analyte This Phase

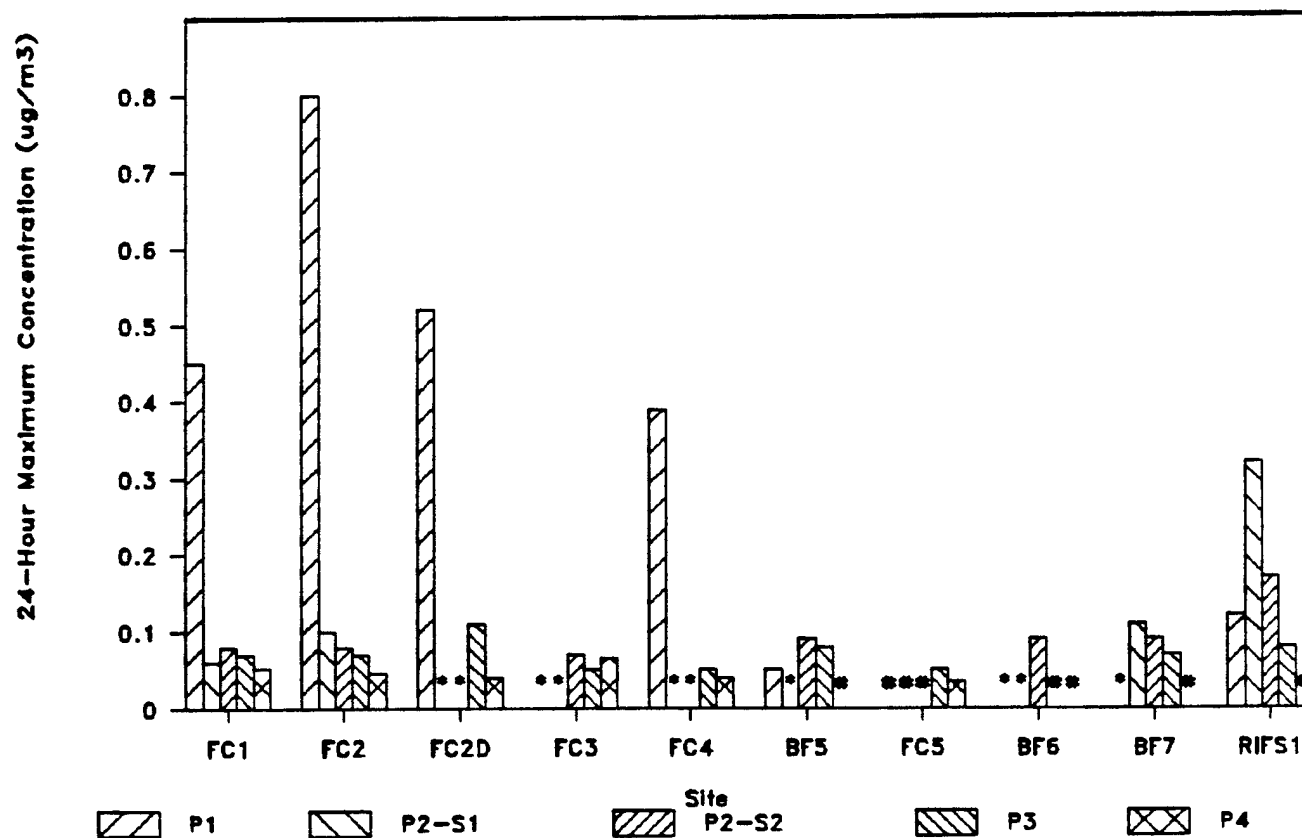
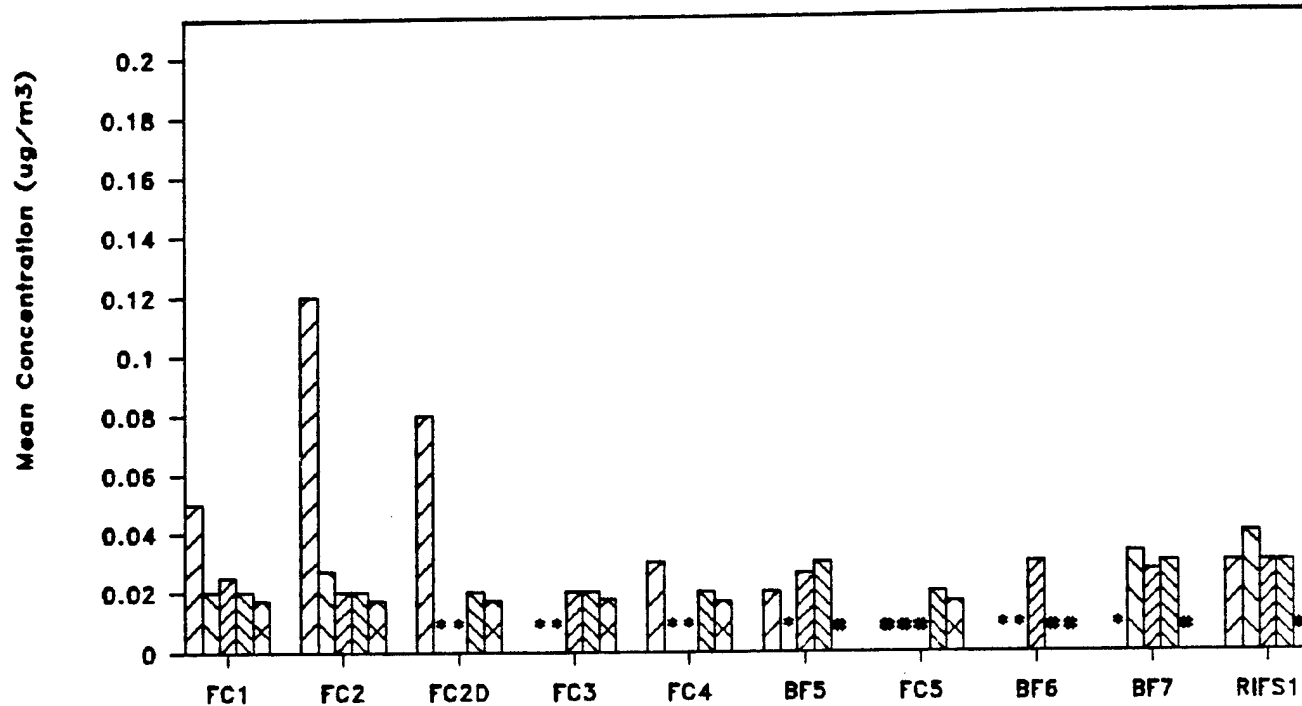
The CMP high event sampling around the South Plants complex showed that there was evidence of a chloroform source in that area. A maximum level of $9.65 \mu\text{g}/\text{m}^3$ was reported on August 9, 1990, at AQ8, just north of the South Plants complex. This level was well above any Phases 3 or 4 results at the former Basin F sites. Average chloroform concentrations at the RMA boundary were roughly equivalent to the data from the Basin F area, but all CMP data were collected on predicted high events, yielding conservative estimates of actual average values.

As a result of this analysis, it is evident that Basin F remedial activities were a source of chloroform during Phase 1 and to a lesser extent during Phase 2. It also is apparent that chloroform continued to be emitted from the former Basin F through Phases 3 and 4, and could serve as an indicator of potential former Basin F emissions. There is apparently a background chloroform source, possibly from either RMA or off-site sources, but the exact nature of this source is not easily determined. The CMP performed analyses of VOCs around the South Plants area during all three sampling years, and generally concluded that the South Plants complex was a source of chloroform. Nevertheless, it was also emitted from Basin F, and if sampling were used carefully, it could serve as an indicator compound for emissions from the former Basin F.

4.6.4.6 Chlorobenzene

Chlorobenzene (ClC_6H_5) was also a target compound during the RI, but was not detected. The mean and extreme chlorobenzene results are shown in Figure 4.6-9 for all Basin F sampling sites. In Phase 1 there was a notable tendency for higher concentrations at BF-2 and a secondary maximum concentration at BF-1. Results from samples at the remaining sites and through the later phases continued to show some detections near the CRL, but there is no clear spatial pattern.

Basin F might have been acting as a source of chlorobenzene during Phase 1, but levels dropped off to consistent background concentrations during the later phases. No source for the chlorobenzene could be determined. Chlorobenzene levels detected during the CMP high event program during Phase 4 was equivalent to the average levels around the former Basin F.



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Figure 4.6-9

Mean and Maximum Concentrations for
Chlorobenzene by Site, by Phase

* Not Detected

Not an Analyte This Phase

4.6.4.7 Dicyclopentadiene

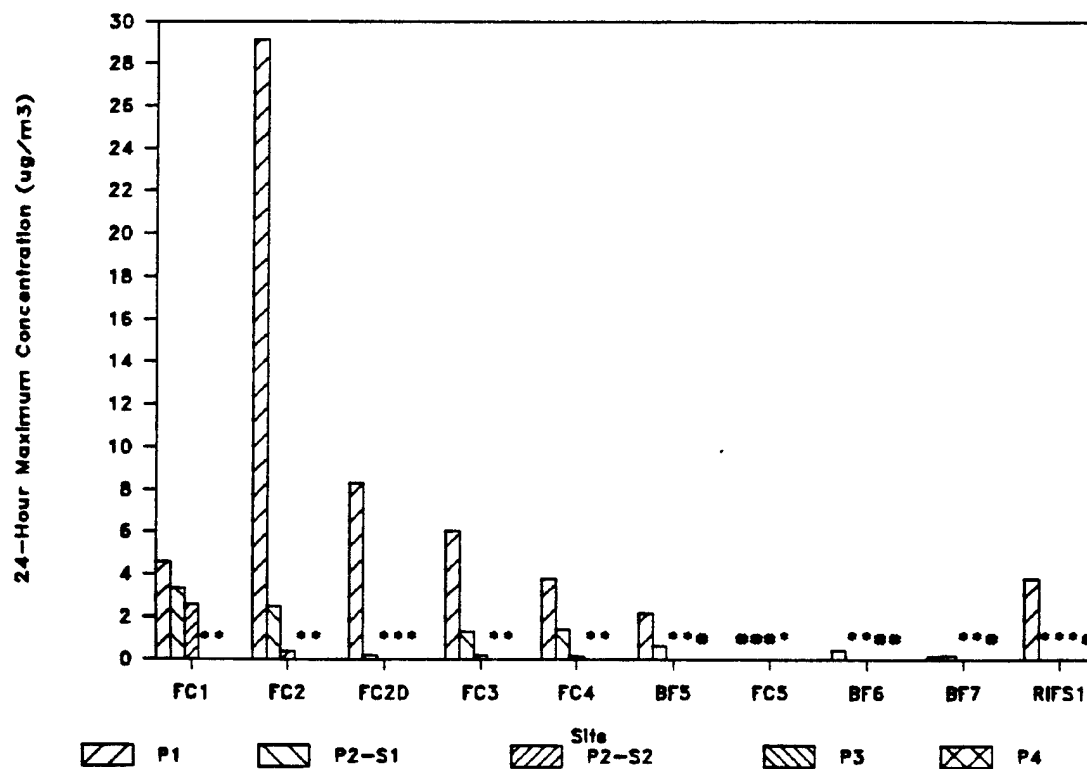
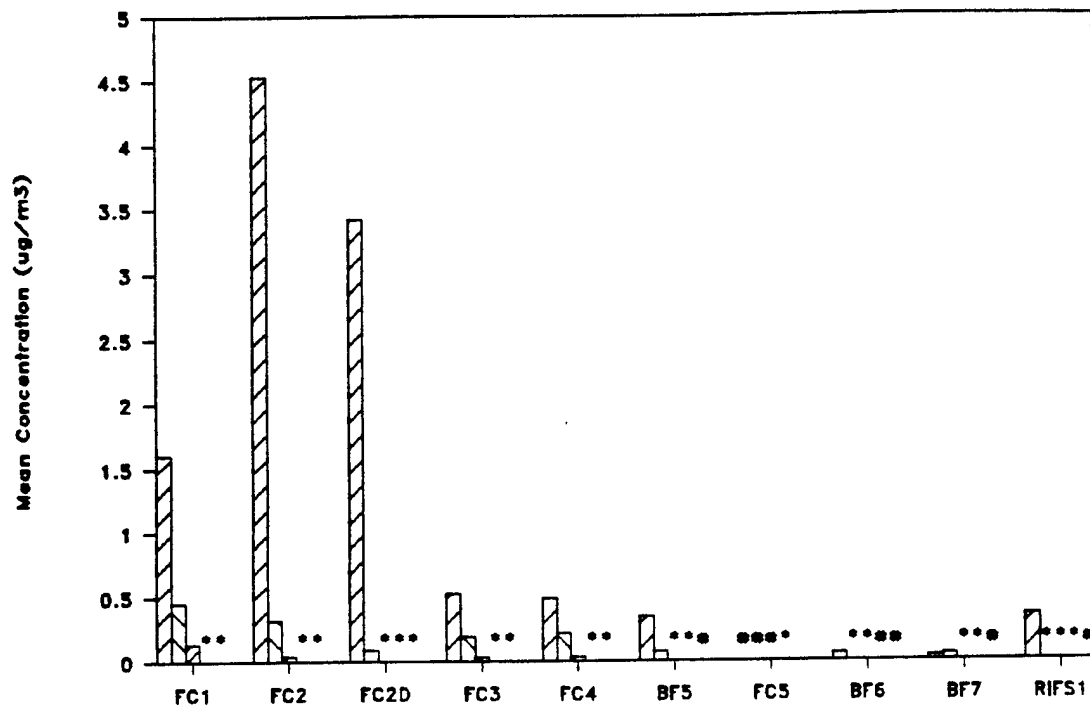
Dicyclopentadiene (DCPD) was identified as a potential contaminant in the Basin F materials. It was not sampled as a target analyte during the RI program. During the Basin F remedial activity, however, it was identified as a target compound and was routinely reported during Phase 1. Figure 4.6-10 presents the results of the DCPD sampling. These results indicated a distinct maximum concentration at BF-2, which was confirmed by analysis of BF-2C data. A secondary average maximum occurred at BF-1.

During Phase 2, DCPD continued to be detected, especially at the Basin F perimeter sites, but levels were substantially below those of Phase 1. BF-1 had the highest average concentrations during this phase. During Phases 3 and 4, DCPD was not detected at any of the sampling sites, and it was detected in only one CMP high event sample.

The results indicate that Basin F was a source of DCPD during Phase 1 remedial activity and that emissions dropped off during Phase 2 as intrusive activity ceased. There was evidently no significant source of DCPD during the latter phases.

4.6.4.8 1,2-Dichloroethane

The analyte 1,2-dichloroethane (12DCLE) was a target analyte for the RI program, but was not detected. During Phase 1, maximum 12DCLE levels were detected at BF-2 and BF-2C. During Phase 2, there were several detections of 12DCLE at BF-2, but these were not confirmed by the collocated site. Intermittent detections of 12DCLE continued through the subsequent phases, with no clear pattern associated with the results. During Phase 4, there were repeated detections, but with no clear pattern. When 12DCLE was detected, it was most often reported on the backup Tenax-and-charcoal trap only. Many of the remaining detections from the backup traps were more than 25 percent of the Tenax traps. The results of the 12DCLE sampling are shown in Figure 4.6-11.



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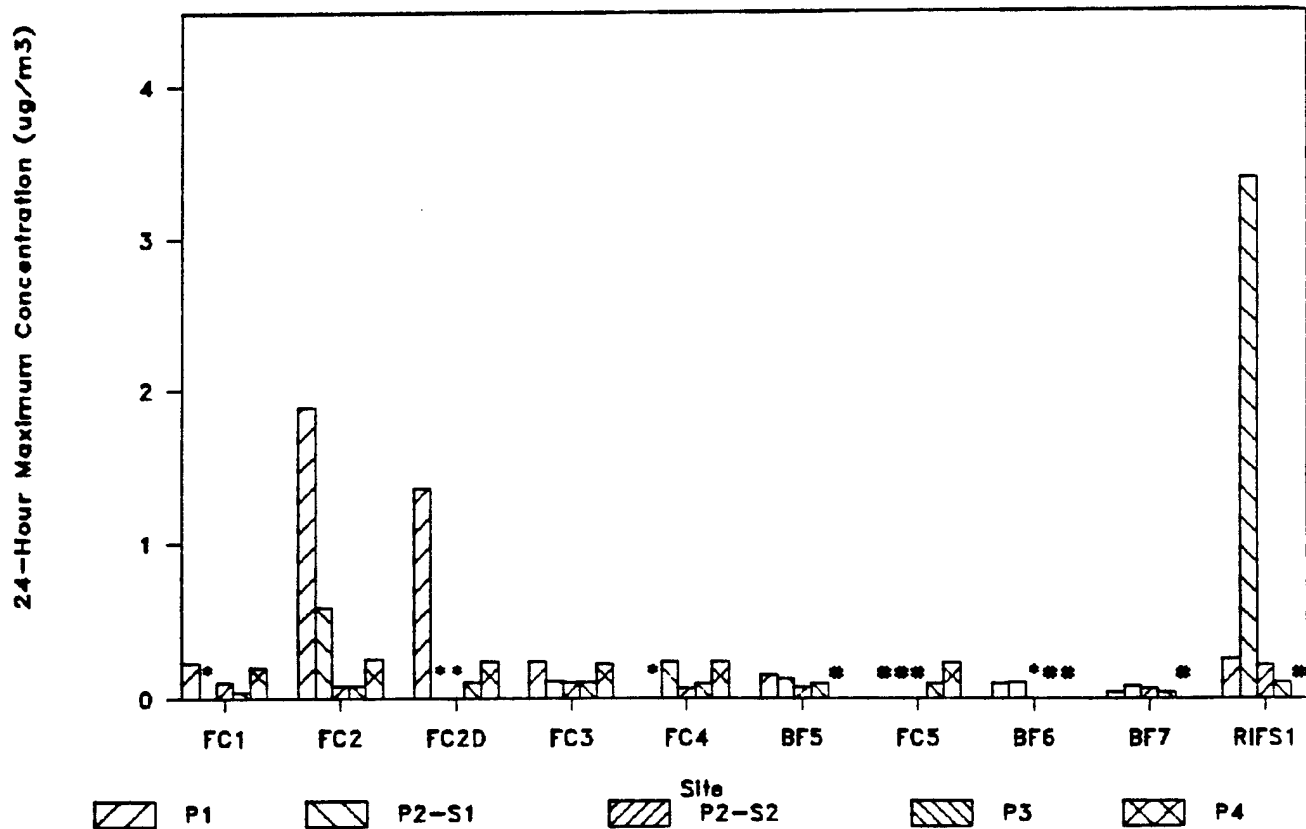
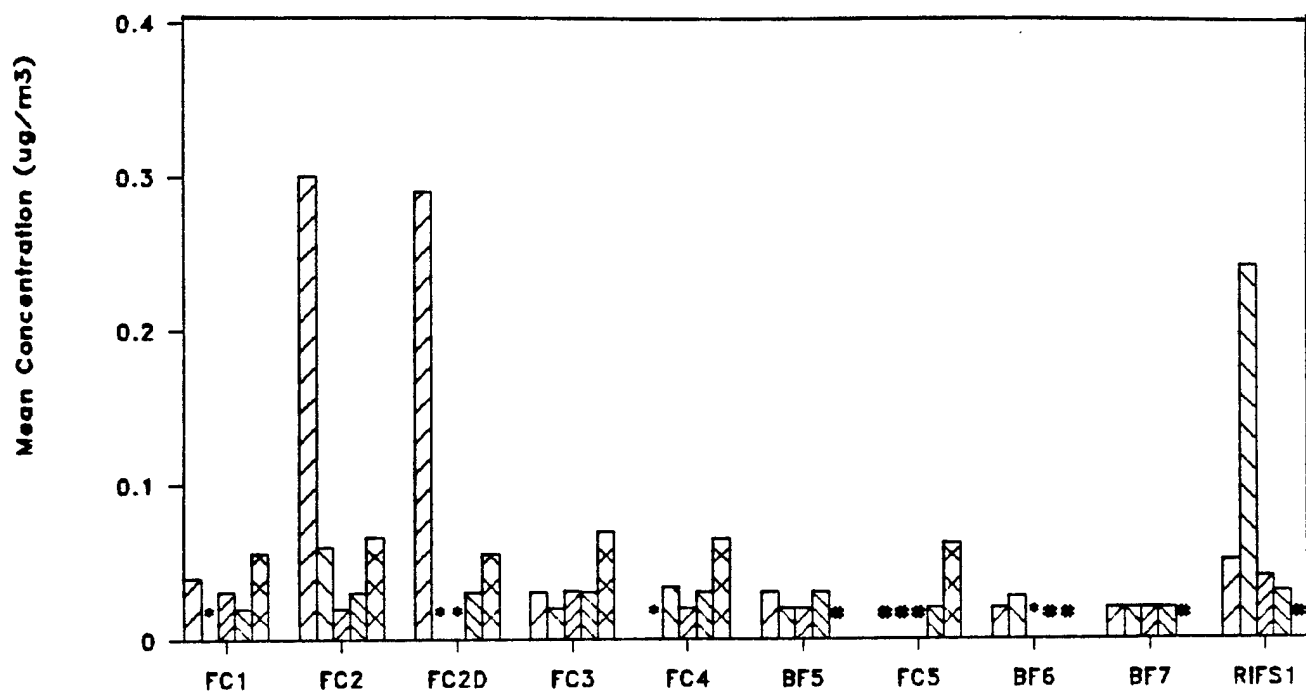
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Figure 4.6-10

Mean and Maximum Concentrations for
Dicyclopentadiene by Site, by Phase

* Not Detected

Not an Analyte This Phase



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Figure 4.6-11

Mean and Maximum Concentrations for
1,2-Dichloroethane by Site, by Phase

* Not Detected

Not an Analyte This Phase

During Phase 4, average 12DCLE concentrations were about $0.07 \mu\text{g}/\text{m}^3$, and maximum values were at or just below $0.25 \mu\text{g}/\text{m}^3$ at all sites. The average 12DCLE concentrations for the CMP high events at RMA boundary sites were similar to those of the IRA-F program. This pattern indicated a steady source whose impact on the former Basin F sites was fairly small, and whose origin was most likely a non-RMA source.

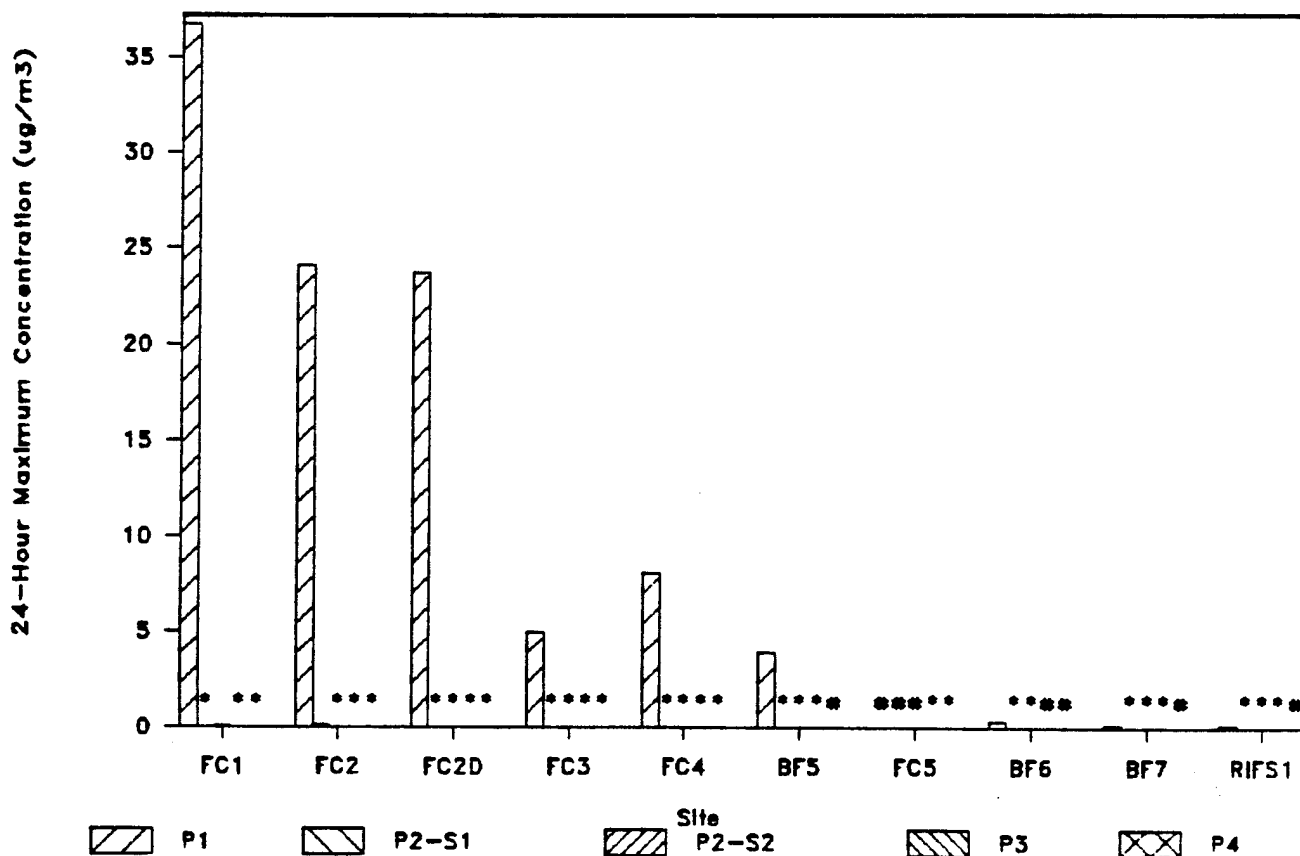
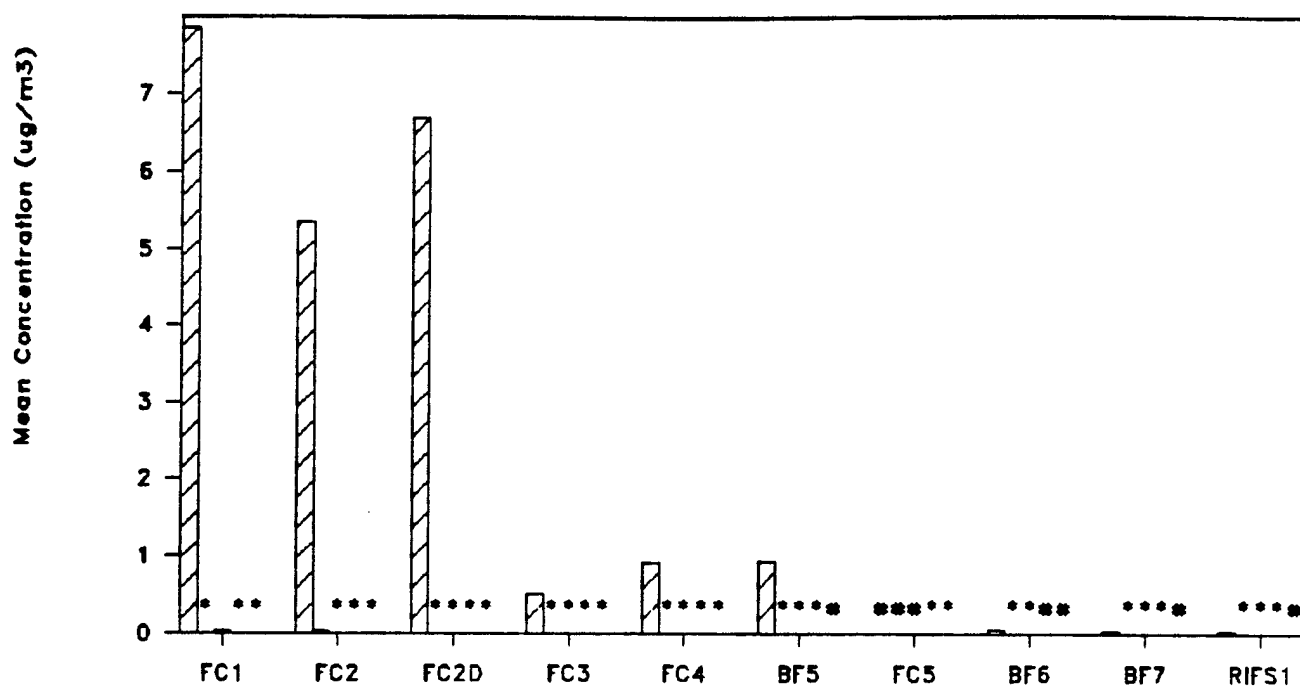
4.6.4.9 Dimethyl Disulfide

Dimethyl disulfide (DMDS) was a target analyte that appears to be unique to the Basin F or RMA environment. It was not detected during the RI. Figure 4.6-12 shows the average and maximum DMDS concentrations for each phase at each Basin F site. During Phase 1 there was a definite peak in concentrations at the Basin F downwind sites (BF-1 and BF-2), with much smaller concentrations at the upwind and the distant sites. During Phase 2, DMDS was detected only twice at relatively low concentrations, and it was not detected at all under the IRA-F program or the CMP during Phases 3 and 4.

The results clearly indicated that Basin F was a source of DMDS during remedial activities. The spatial distribution of average values was similar to that of BChPD, confirming a Basin F source. Following remedial activities, there was no evidence of a source of DMDS in the ambient data.

4.6.4.10 Ethylbenzene

Ethylbenzene (ETC_6H_5) was not detected during the RI, but was continually detected during the subsequent programs. A graphical depiction of the mean and extreme concentrations of ethylbenzene is presented in Figure 4.6-13. During Phase 1, there was a clear maximum impact at BF-1 and BF-2, with comparable values at RIFS1. The mean concentrations at other Basin F sites were about half of those at BF-1 and BF-2, showing a pattern that was not completely consistent with that of DMDS or BChPD. During Phase 2, Stage 1 mean concentrations were fairly uniform across the Basin F sites. Interestingly, average concentrations at BF-3 were comparable to those at the downwind sites with comparable levels at the RIFS sites. The mean levels of ethylbenzene continued to decrease into Phase 2 and through Phases 3 and 4. In



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Figure 4.6-12

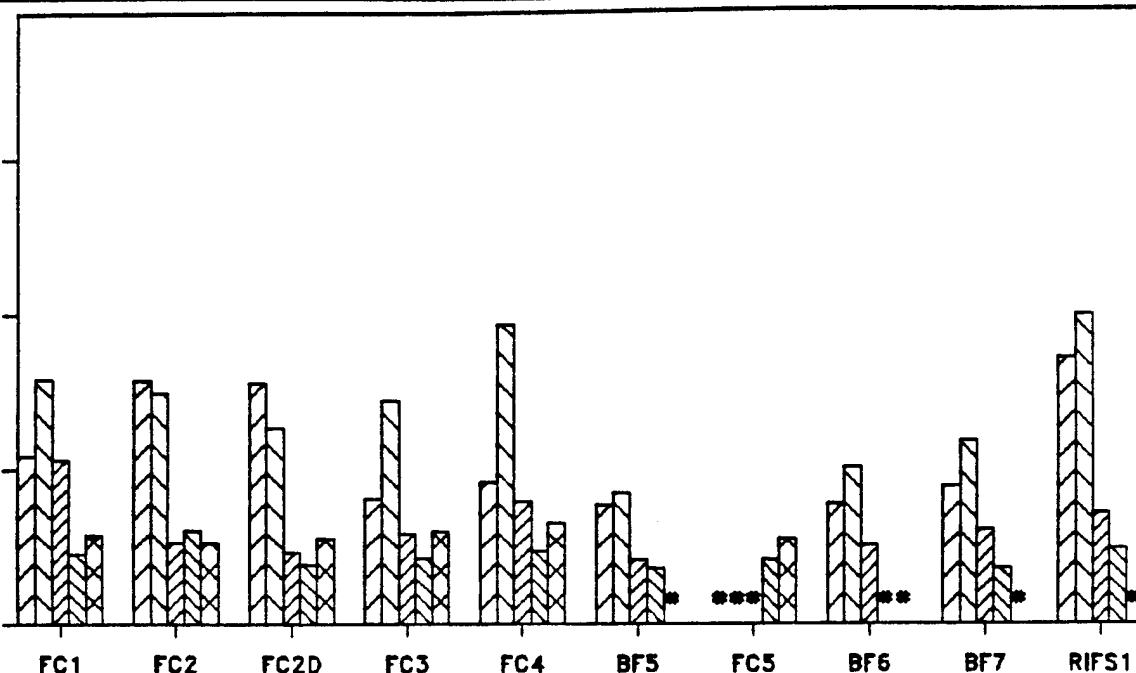
**Mean and Maximum Concentrations for
Dimethyl Disulfide by Site, by Phase**

* Not Detected

Not an Analyte This Phase

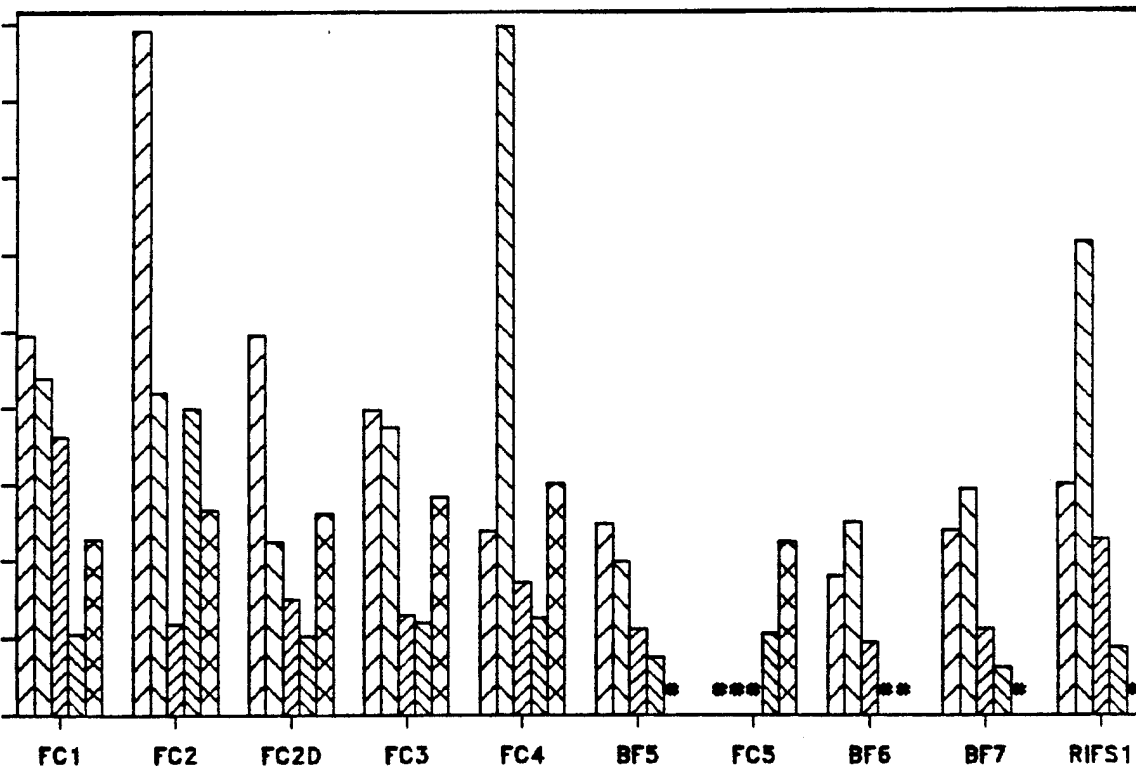
Mean Concentration ($\mu\text{g}/\text{m}^3$)

3
2
1
0



24-Hour Maximum Concentration ($\mu\text{g}/\text{m}^3$)

9
8
7
6
5
4
3
2
1
0



P1
 P2-S1
 P2-S2
 P3
 P4

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Figure 4.6-13

Mean and Maximum Concentrations for
Ethylbenzene by Site, by Phase

Not an Analyte This Phase

Phase 4 all sites recorded average values of about $0.6 \mu\text{g}/\text{m}^3$. Under the CMP high event program, slightly higher average concentrations (1.0 to $1.4 \mu\text{g}/\text{m}^3$) were sampled at the RMA boundary sites AQ1 and AQ5.

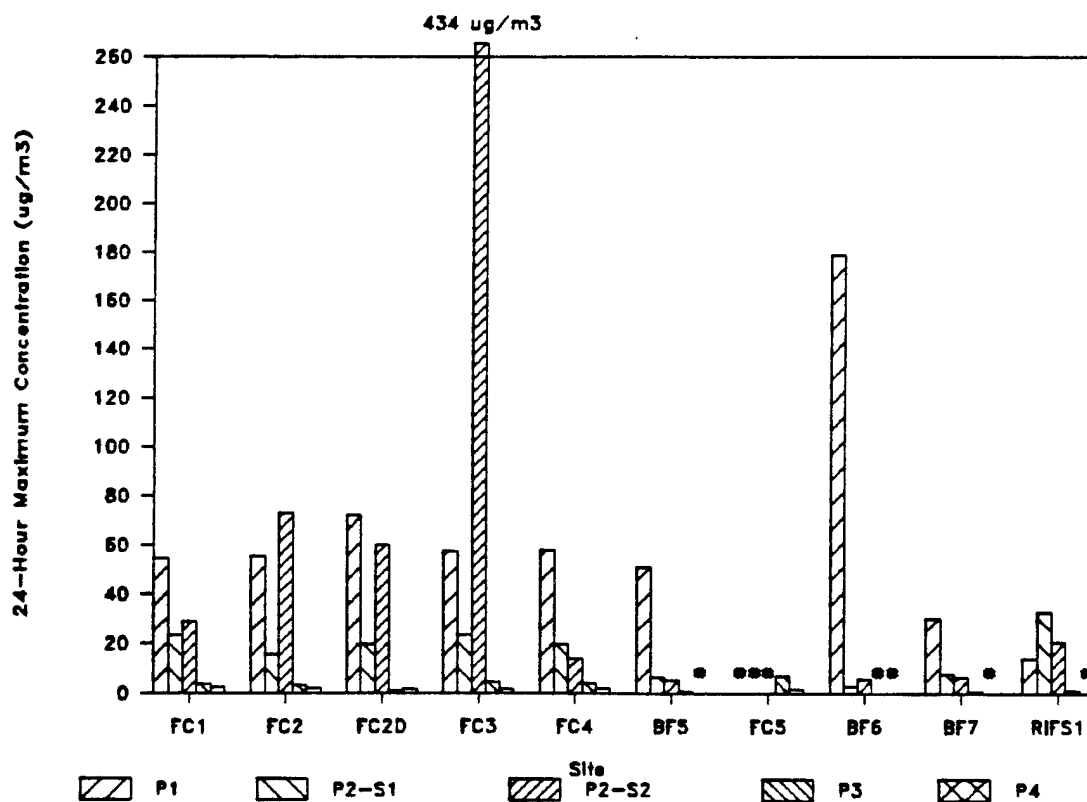
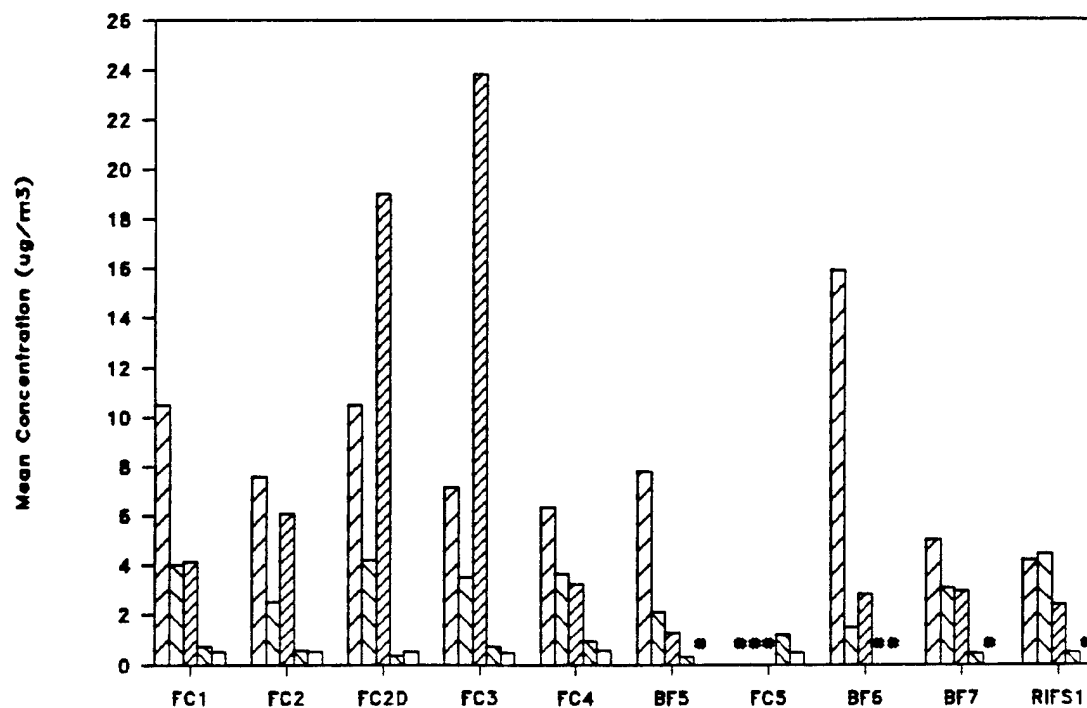
During remedial activity, Basin F (or Basin F operations) was a source of ethylbenzene, but as remedial activities ceased, an evenly distributed pattern of background concentrations became evident. Since ethylbenzene is emitted from gasoline and diesel fuel, it is likely that the heavy equipment operations of the Basin F remedial action were responsible for the maximum impacts. During Phases 1 and 2 the RIFS sites reported values near the Basin F maximum values, and since the CMP Phase 4 values at boundary sites were highest, the urban Denver traffic was evidently responsible for a measurable background concentration of ethylbenzene.

4.6.4.11 Methyl Ethyl Ketone

Methyl ethyl ketone (MEK) was a target compound only for the Phase 1 and Phase 2 Basin F monitoring program. The highest maximum results were detected during Phase 2, Stage 1. Given the pattern of average results shown in Table 4.6-2, it is unlikely that Basin F was a source of MEK. As a component of the urban airshed, the high levels of MEK were likely due to a combination of urban emissions and the typical strong inversion conditions that occur in the Denver metropolitan area in mid-winter.

4.6.4.12 Methylene Chloride

Methylene chloride (CH_2Cl_2) was on the target list for the RI program, and was the most frequently detected compound during the seven RI events. It continued to be detected under the subsequent programs. The graphical depiction of the mean and extreme values is shown in Figure 4.6-14. The extremely high values of methylene chloride must be used with great caution. These results were well above the laboratory's ability to provide solid estimated values. In general the high values were reported at all sites during Phases 1 and 2, with no consistent pattern. By Phase 4, the methylene chloride levels stabilized considerably, with an average background concentration (confirmed by CMP) of about $0.5 \mu\text{g}/\text{m}^3$.



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Figure 4.6-14

Mean and Maximum Concentrations for
Methylene Chloride by Site, by Phase

Not an Analyte This Phase

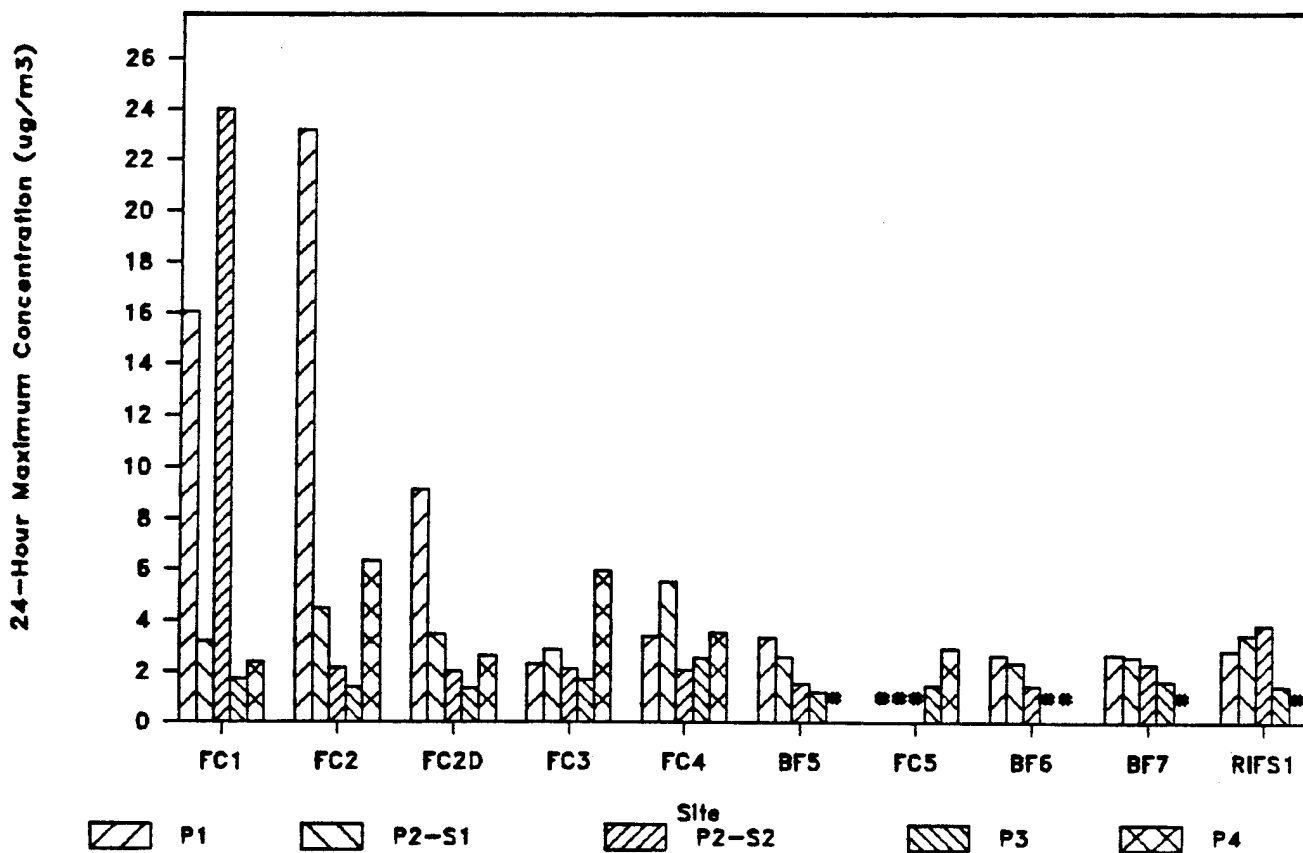
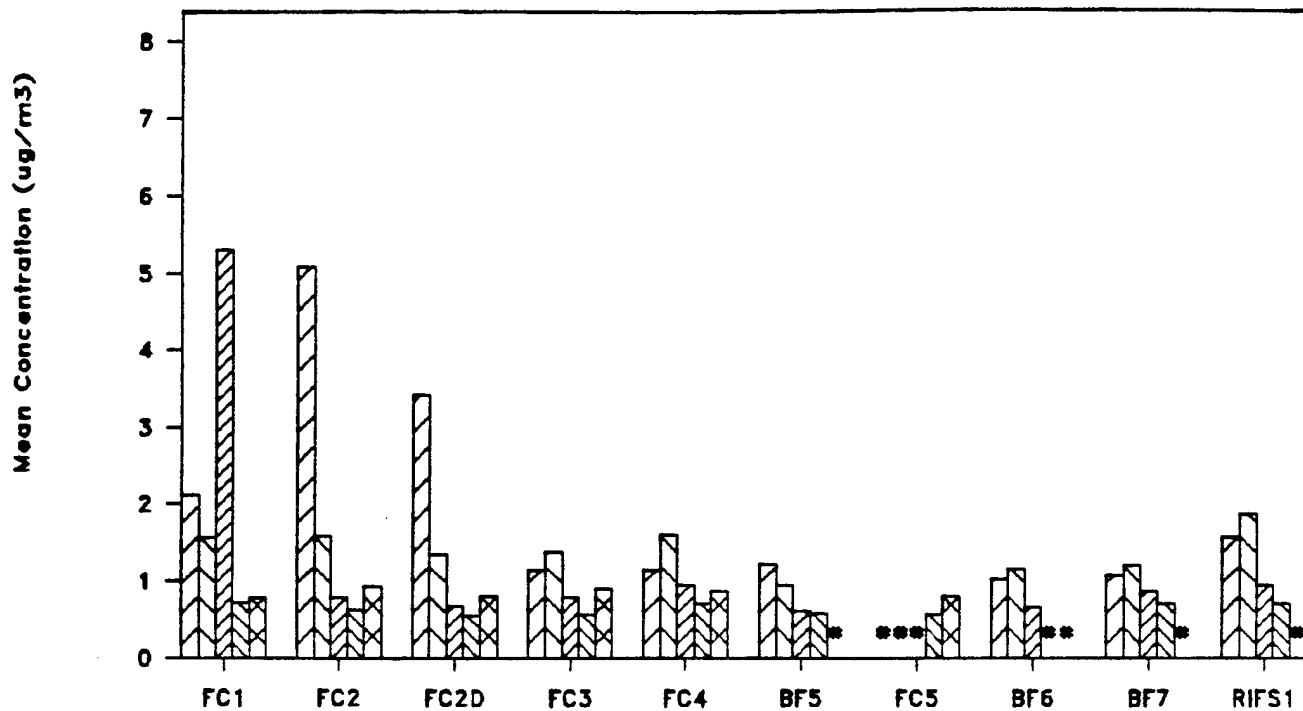
Methylene chloride is a common laboratory contaminant, and this may have contributed to some of the spurious high values seen in Phases 1 and 2. Basin F activities may have impacted levels of methylene chloride during Phases 1 and 2, but that impact was masked by the laboratory situation and by the background concentrations. During the latter phases, there was no evidence of a source of methylene chloride near the former Basin F.

4.6.4.13 Tetrachloroethylene

Tetrachloroethylene (TCLEE) was on the target list for the RI, but was not detected. The results of the sampling around Basin F are presented for each phase at each site in Figure 4.6-15. During Phase 1, the greatest impacts were seen at BF-1 and BF-2, with a secondary maximum concentrations at RIFS1. In Phase 2, Stage 1, a maximum level was detected at RIFS1 and average concentrations at all other sites were evenly distributed. In Phase 2, Stage 2, there was one relatively high value at BF-1, but otherwise there was no distinct pattern in the TCLEE results. The same pattern persisted through Phases 3 and 4, with average concentrations of about $0.8 \mu\text{g}/\text{m}^3$ during Phase 4.

Under the CMP high event program, the highest average values of TCLEE were detected at sites on the western boundary (AQ1 with a concentration of $1.8 \mu\text{g}/\text{m}^3$) and southern boundary (AQ5 with a concentration of $1.3 \mu\text{g}/\text{m}^3$). A maximum concentration of $4.5 \mu\text{g}/\text{m}^3$ was detected at AQ5 during the December 1989 high event. The measured values were within the range of extreme values sampled at the former Basin F sites during Phase 4.

There was probably an RMA source of TCLEE during Phase 1 operations. In subsequent phases, however, no consistent pattern of mean concentrations was evident around the former Basin F. Sampling data indicate there was likely no source of TCLEE in the Basin F area following remedial activities. There is evidence, supplied by CMP results, that urban Denver sources contributed significantly to measured RMA concentrations.



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Figure 4.6-15

Mean and Maximum Concentrations for
Tetrachloroethylene by Site, by Phase

Not an Analyte This Phase

4.6.4.14 Toluene

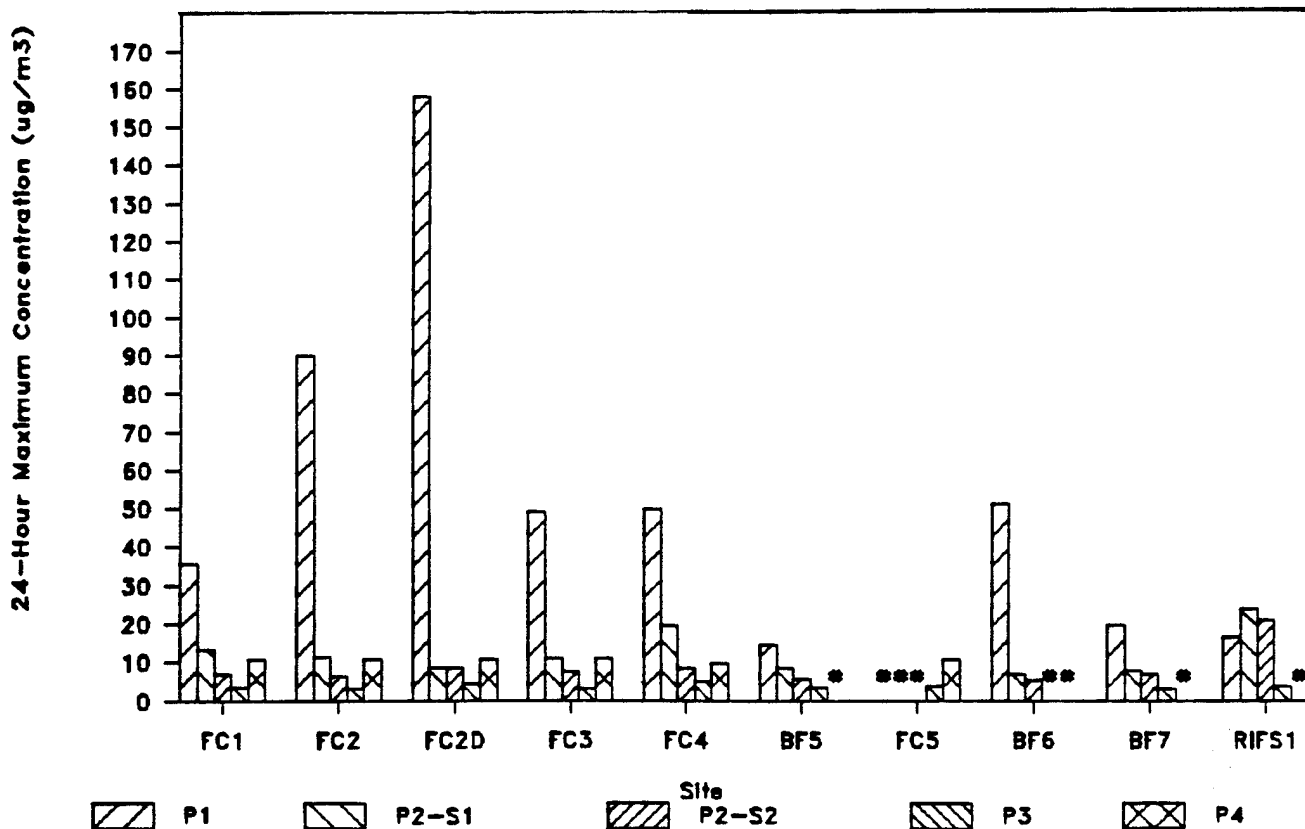
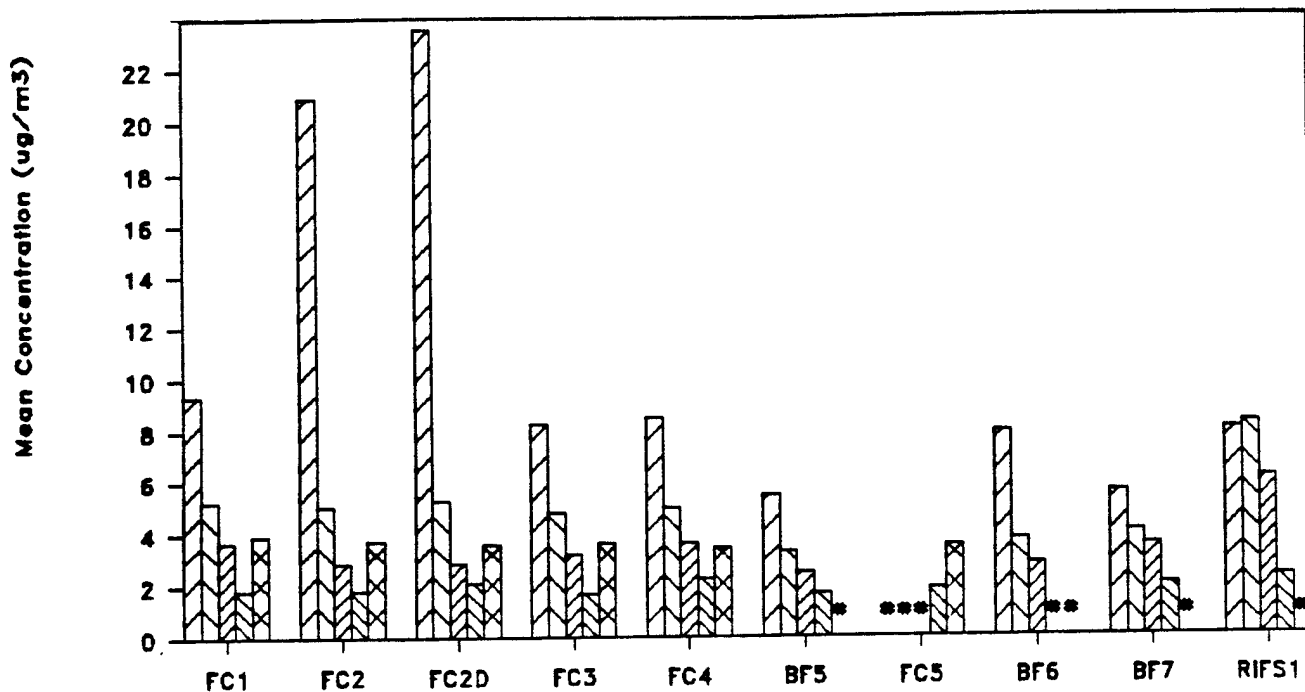
Toluene (or methyl benzene, MEC_6H_5) was on the target list for the RI program but was not detected. Results of subsequent sampling around Basin F are presented graphically in Figure 4.6-16. Some very high estimated values were obtained during Phase 1, but on the average, concentrations at BF-2 were notably higher than those of the other sites, which exhibited an even distribution pattern. In both stages of Phase 2, toluene concentrations around Basin F continued to be evenly distributed, but relative maxima were clearly evident at the RIFS sites. During Phases 3 and 4, concentrations of toluene at all sites were roughly equivalent, with an overall background mean concentration of just under $4 \mu\text{g}/\text{m}^3$ for Phase 4.

The CMP high event sampling around Basin F also showed relatively high toluene values during Phase 1. During Phases 3 and 4 RMA boundary toluene levels were comparable to those around the former Basin F, except that average values on the north and east boundaries were notably lower than those on the west and south boundaries. During the CMP high event on June 27, 1990, in the South Plants area, toluene levels slightly above $11 \mu\text{g}/\text{m}^3$ were detected.

It is evident that Basin F remedial activities were a source of toluene during Phase 1, particularly at the downwind site BF-2. Toluene could have been emitted by both the waste handling and by the heavy equipment emissions associated with remediation. In Phase 2, the Denver metropolitan area or perhaps the more localized traffic along the State Highway 2 corridor northwest of RMA, were the likely sources of the measured toluene. There was no evidence of a source near the former Basin F during Phases 3 and 4.

4.6.4.15 Trichloroethylene

Trichloroethylene (TRCLE) was also on the target list for the RI program, but was not detected. During the IRA-F program TRCLE was detected during all phases, and the mean and maximum results are shown in Figure 4.6-17. The Phase 1 levels of TRCLE were relatively high compared to other phases, but the mean pattern did not show the relative maxima at BF-1 or BF-2, which would have been expected from a Basin F source. In Phase 1, both BF-2 and RIFS1 had the



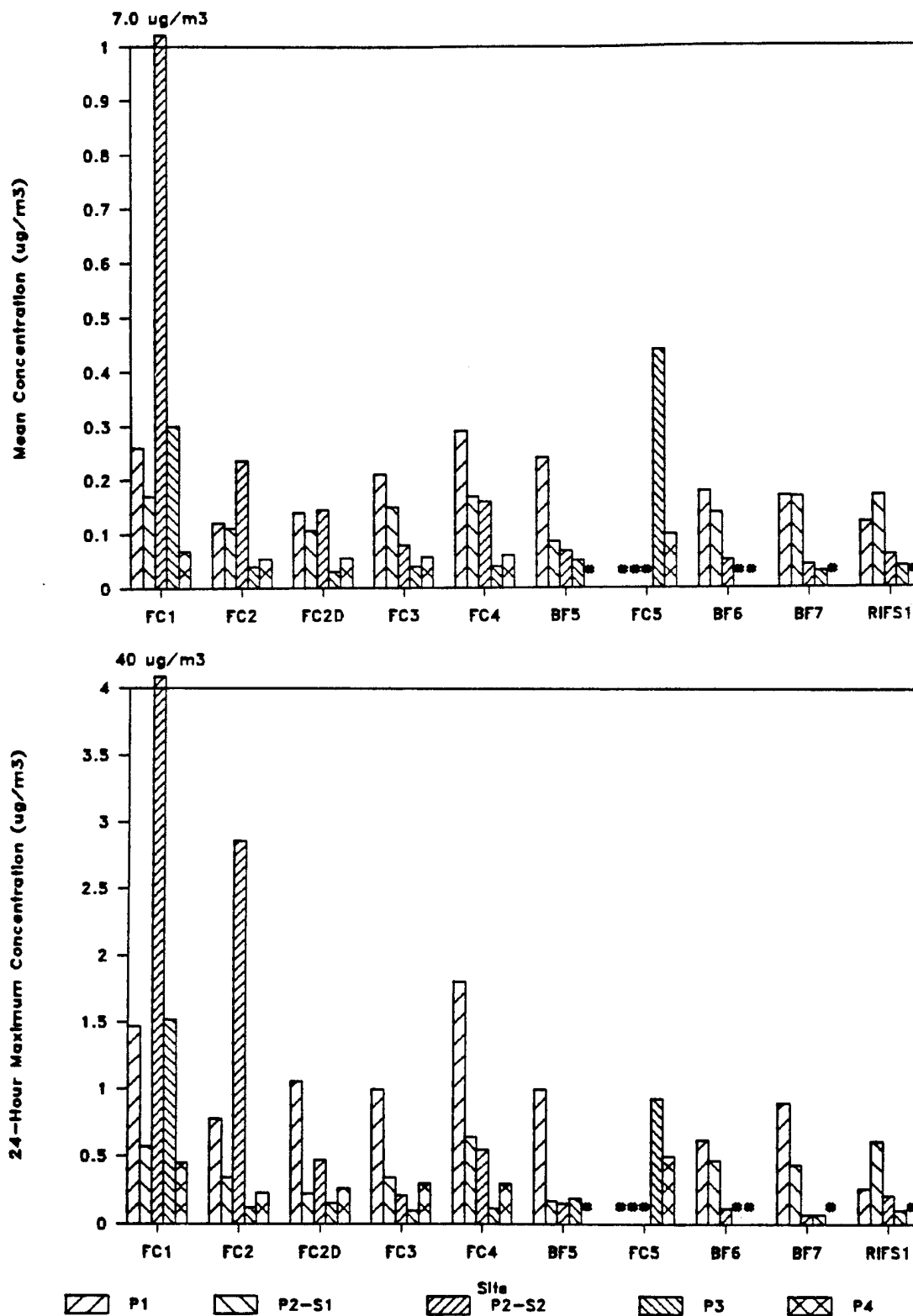
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Figure 4.6-16

Mean and Maximum Concentrations for
Toluene by Site, by Phase

* Not an Analyte This Phase



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Figure 4.6-17

Mean and Maximum Concentrations for
Trichloroethylene by Site, by Phase

Not an Analyte This Phase

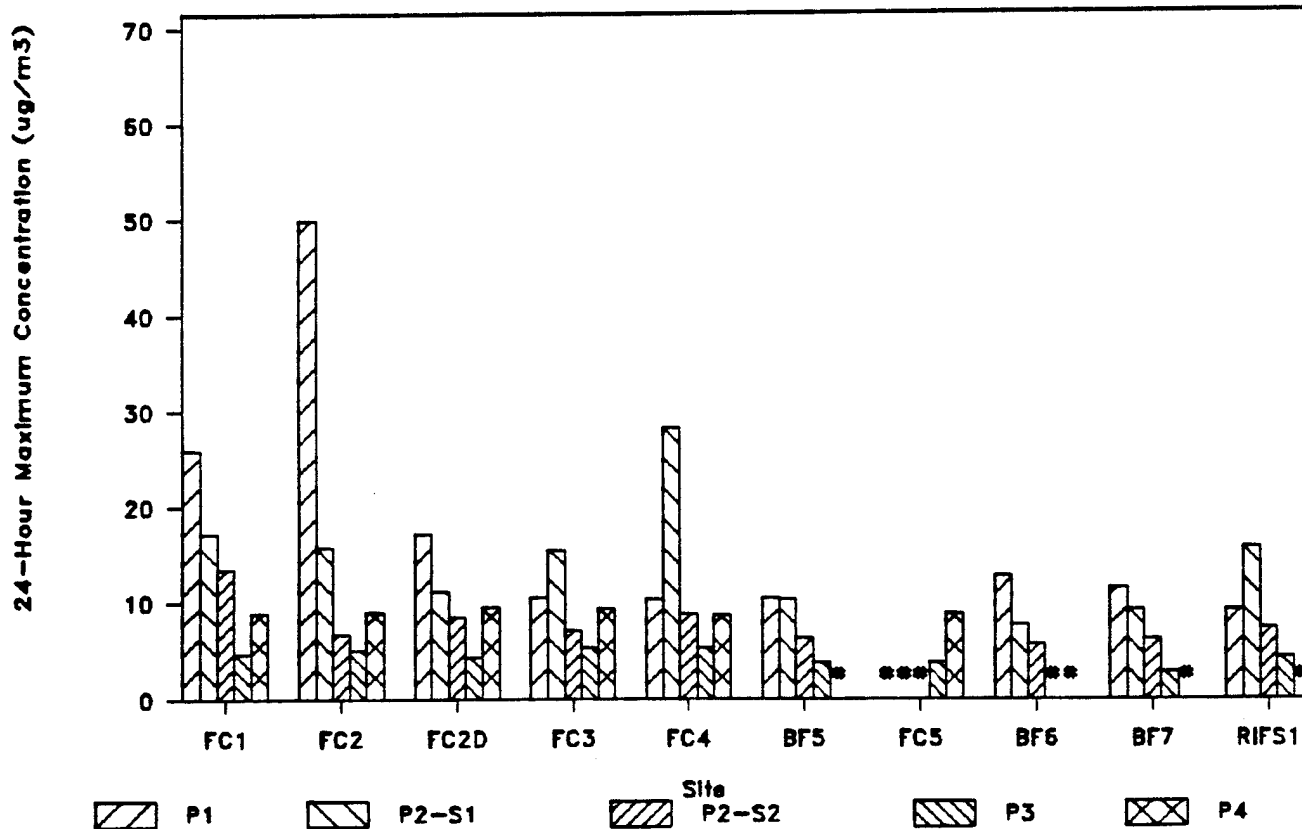
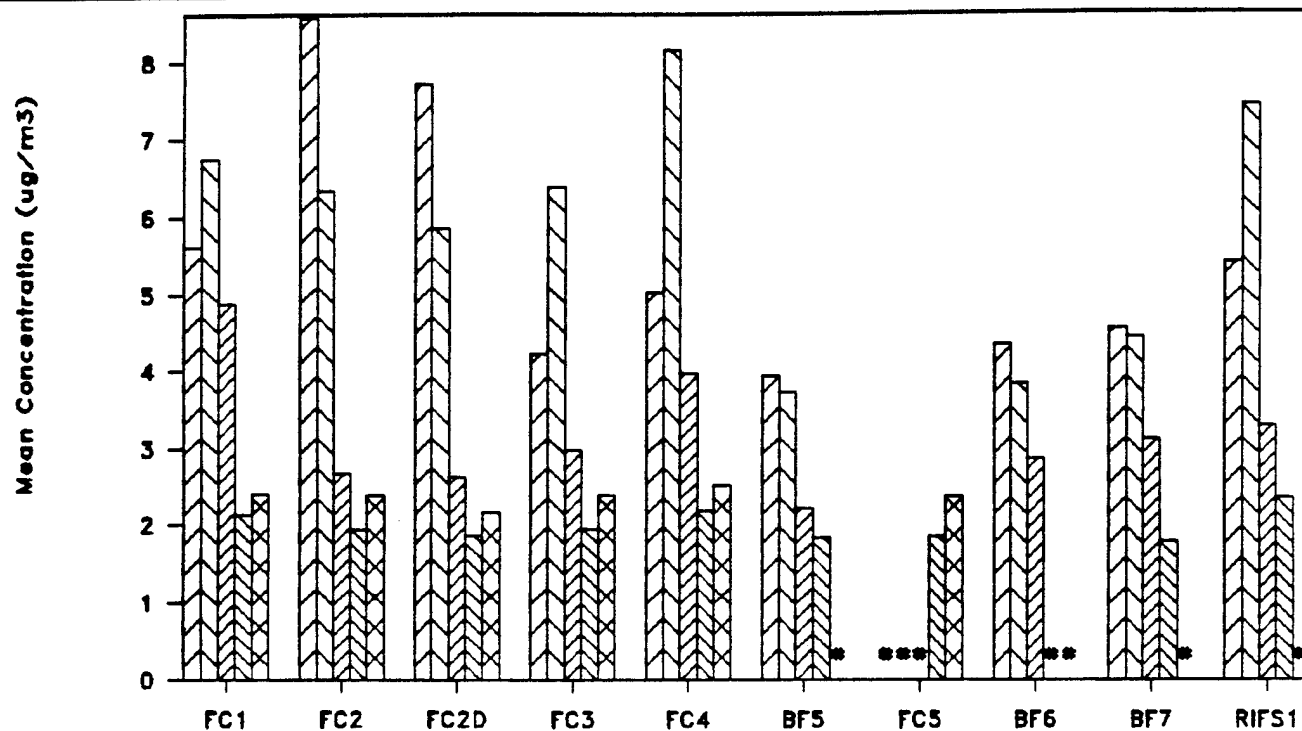
lowest average concentrations, and the higher average concentrations were noted at widely separated sites. Except for one unusually high level at BF-1 in Phase 2, Stage 2, the average concentration of TRCLE was relatively evenly distributed over the sampling sites. In Phase 3, as illustrated in Figure 4.6-16, notably higher average concentrations were sampled at sites FC-1 and FC-5, north of the former Basin F and near Pond A. In Phase 4, average concentrations ranged from 0.05 to 0.10 $\mu\text{g}/\text{m}^3$, with a relative maximum level at FC-5 and a secondary maximum at BF-1. Average CMP high event values were higher at the western boundary (0.14 $\mu\text{g}/\text{m}^3$ at AQ1) and lower at the eastern boundary (0.05 $\mu\text{g}/\text{m}^3$ at AQ4) during Phase 4.

Some Basin F operations could have led to the relatively high TRCLE levels in Phase 1, but the nature of this source is not clear. In later phases, a homogeneous background pattern of TRCLE emerged. A relatively minor source of TRCLE, localized north of the former Basin F or near Pond A, could have led to the observed concentrations in Phases 3 and 4. This feature is difficult to confirm with the available results.

4.6.4.16 Total Xylenes

Xylene compounds were also on the target list for the RI program, but there were no detections during any of the seven sampling episodes. Under the Basin F remedial monitoring program, data were reported as total xylenes, but under the other programs, the results were separated into ortho-xylene (o-xylene, 1,2-dimethyl benzene, or 12DMB) and a combined meta- and para-xylene (m- and p-xylene, or XYLEN). For comparative purposes, only the total xylene results are presented and discussed here. The actual mean and maximum values are documented in Tables 4.6-2 and 4.6-3 for each site and phase.

Figure 4.6-18 provides the mean and maximum pattern of total xylene concentrations by phase and site. In Phase 1, there was clearly a maximum average xylene concentration at BF-2, confirmed by the results at BF-2C. Overall, the Phase 1 levels were slightly above those of the next phase and were much greater than those of Phases 3 and 4. In both stages of Phase 2, the total xylene concentrations remained roughly comparable to those of Phase 1, but no pattern was



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Figure 4.6-18

Mean and Maximum Concentrations for
Total Xylenes by Site, by Phase

Not an Analyte This Phase

established. In Phases 3 and 4, mean total xylene concentrations were stabilized showing no evidence of a pattern of maximum concentrations. The individual components of total xylenes showed the lack of pattern. The CMP high event results for Phase 4 showed slightly higher average total xylene results along the western and southern RMA boundary than at other sites.

The results indicate that during Phase 1, Basin F remedial actions were a likely source of xylenes. In Phase 2, the levels remained high but there was no evidence of a local source. Based on the comparison of the RIFS results and the Basin F results, it is evident that a larger, urban area source was probably responsible for many of the observed concentrations. During Phases 3 and 4, the concentrations around the former Basin F became homogeneous, giving an overall average total xylene concentration of about $2.3 \mu\text{g}/\text{m}^3$. The background concentrations of each of the two components stabilized as well. The urban area sources, including traffic and industry were probably responsible for the observed background concentration pattern.

4.6.4.17 Other Compounds

A quick review of Tables 4.6-2 and 4.6-3 provide a suitable analysis of the results for other target analytes. Acetone was a target analyte for the Basin F remedial action program only, and it was included for the convenience of the laboratory. No distinct pattern emerged, and acetone was not included as a target compound for the remaining programs. The compound 1,1,2-trichloroethane, was included as a target compound, but only sporadic detections were observed and no pattern was evident. Similarly detections of 1,1-dichloroethane, methyl isobutyl ketone and trans-1,2-dichloroethylene were rare and no consistent pattern was established. Hexachlorobutadiene was added to the target list during the Basin F remedial action program during Phase 2, but there were no detections, and it was excluded from subsequent programs. For all these compounds, it can be concluded that there was no evidence of a Basin F source during the sampling periods.

4.6.5 Summary of Apparent Sources of Volatile Organic Compounds

Several VOC target analytes including benzene, chloroform, ethylbenzene, toluene and dimethyl disulfide were identified through Basin F sampling programs as potential Basin F emissions. These compounds were generally lower in the former Basin F vicinity during Phase 4. Sampling during Phase 4 indicated an apparent shift in high VOC concentrations from the Basin F area to the RMA boundary, indicating urban impacts upon RMA. Both the average and the 24-hour maximum concentrations for chloroform, ethylbenzene, toluene, methyl isobutyl ketone, o-xylene, tetrachloroethane, and m- and p-xylene were measured at AQ1, a western boundary site close to the metropolitan Denver influences. Other analytes including chloroform, carbon tetrachloride and methylene chloride were recorded in higher concentrations around Basin A and the South Plants area, where new remedial tasks have caused ground surface disturbances.

Many of the VOC levels measured on RMA during Phase 4 were actually below those in the Denver metropolitan area. After completion of remediation, many VOC concentrations dropped to typical urban background levels. The CDH has identified numerous large point sources of VOC emissions, and acknowledges the existence of many small sources as well. Lists available from CDH enumerate large point sources and the estimated tons per year emissions of those sources. A condensed listing of sources in the vicinity, and their estimated emissions was presented in the Air Quality Data Assessment Report for the CMP (Stollar, 1991), and will not be duplicated here. Small point sources include such small business establishments as painting shops, gasoline filling stations, automobile repair shops, dry cleaners and business copy centers. A fair number of such businesses are in proximity to RMA. Other sources of VOC emissions include diesel and gasoline burning vehicles, aircraft and construction equipment.

4.6.6 Nontarget Volatile Organic Compounds

Selected VOC samples were also analyzed for nontarget compounds. Classes of similar detected compounds were formed into different chemical groups. Each detected compound was placed into the applicable group and statistics were calculated for each group of compounds. Analytical results from all Tenax tube analyses were handled separately from all Tenax-and-charcoal tubes

analyses because all compounds detected on one tube could not always be matched with the compounds detected on the other. For information purposes, Tables 4.6-4 through 4.6-19 summarize the mean and extreme concentrations of groups of nontarget compounds in the Tenax and Tenax-and-charcoal results, by phase, for all sites taken collectively. During Phase 3, samples from 1 day per month from all sites were analyzed for nontargets. In Phase 4, only FC-2 samples from 1 day per month were analyzed for nontargets.

Analytes collected in the Tenax media included large numbers of alkanes, benzenes, ketones and oxygenated hydrocarbons, which were detected throughout all phases. Naphthalene was present in Phase 1 and Phase 2, to a lesser extent in Phase 3, and not at all in Phase 4. Tenax-and-charcoal tubes also showed a large number of detections of alkanes, ketones and oxygenated hydrocarbons, but relatively fewer benzenes. Several detections of chlorofluorocarbons (Freons) occurred throughout all phases, including detections in field blank samples.

Table 4.6-4 Summary of Phase 1 Nontarget VOC Detections in Tenax Media
($\mu\text{g}/\text{m}^3$)

Compound	No. of Detections	24-Hour Maximum	Mean
Acetates	4	0.381	0.352
Aldehydes	0	0.000	0.000
Alkanes	482	5.120	0.749
Alkenes	19	1.182	0.298
Benzenes	148	7.850	0.813
Cyclic alkanes	17	2.321	0.669
Cyclic alkenes	1	0.197	0.197
Cyclohexanes	27	1.433	0.373
Freons	10	2.578	0.861
Ketones	12	0.719	0.262
Methyl propanoate	1	0.103	0.103
Naphthalenes	11	0.339	0.180
Oxygenated hydrocarbons	2	0.862	0.846

Table 4.6-5 Summary of Phase 2 Nontarget VOC Detections in Tenax Media
($\mu\text{g}/\text{m}^3$)

Compound	No. of Detections	24-Hour Maximum	Mean
Acetates	3	0.130	0.076
Alcohols	2	0.196	0.185
Aldehydes	12	2.749	0.598
Alkanes	1307	6.122	1.096
Alkenes	58	3.667	0.563
Benzenes	351	6.993	0.917
Cyclic alkanes	57	4.693	1.499
Cyclic alkenes	1	0.382	0.382
Cyclohexanes	93	4.152	0.982
Freons	20	11.151	2.101
Ketones	55	1.528	0.640
Naphthalenes	28	1.204	0.303
Oxygenated hydrocarbons	1	2.525	2.525
Sulfur dioxide	14	0.067	0.053
Terpenes	1	0.058	0.058
Unknowns	8	3.484	2.410

Table 4.6-6 Summary of Phase 3 Nontarget VOC Detections in Tenax Media
($\mu\text{g}/\text{m}^3$)

Compound	No. of Detections	24-Hour Maximum	Mean
Acids	2	0.073	0.072
Aldehydes	22	1.825	0.560
Alkanes	620	3.788	0.461
Alkenes	36	0.971	0.168
Benzenes	157	2.909	0.318
Camphor	6	0.106	0.053
Carenes	18	1.370	0.536
Cineole	2	0.103	0.088
Cyclic alkanes	55	1.515	0.390
Cyclic ketones	6	0.180	0.059
Cyclohexanes	58	1.515	0.324
Esters	6	0.073	0.066
Ethyl acetate	6	0.362	0.316
Freons	10	3.534	0.734
Ketones	78	0.727	0.174
Naphthalenes	10	0.109	0.065
Nitrogen containing hydrocarbons	1	0.074	0.074
Oxygenated hydrocarbons	15	0.993	0.181
Phenols	11	0.353	0.145
Silanes	10	0.227	0.115
Unknowns	10	0.320	0.133

Table 4.6-7 Summary of Phase 4 Nontarget VOC Detections in Tenax Media
($\mu\text{g}/\text{m}^3$)

Compound	No. of Detections	24-Hour Maximum	Mean
Aldehydes	4	1.031	0.598
Alkanes	237	3.484	0.256
Alkenes	1	0.074	0.074
Benzenes	60	3.484	0.375
Butanol	1	0.139	0.139
Carenes	2	1.045	0.678
Cyclic alkanes	2	0.173	0.158
Cyclohexanes	4	0.221	0.178
Ketones	20	0.225	0.085
Methyl t-butyl ether	1	0.177	0.177
Oxygenated hydrocarbons	31	1.394	0.221
Phenols	1	0.036	0.036
Unknowns	11	0.697	0.171

Table 4.6-8 Summary of Phase 1 Nontarget VOC Detections in Tenax-and-Charcoal Media ($\mu\text{g}/\text{m}^3$)

Compound	No. of Detections	24-Hour Maximum	Mean
Aldehydes	4	0.137	0.084
Alkanes	182	4.895	0.766
Alkenes	35	5.743	0.329
Benzenes	3	0.058	0.051
Carene	1	0.035	0.035
Cyclic alkanes	26	2.184	0.501
Cyclic alkenes	1	0.061	0.061
Cyclohexanes	55	1.092	0.182
Freons	8	0.811	0.432
Ketones	3	0.372	0.222
Methyl benzoate	6	0.158	0.083
Methyl butanoate	1	0.220	0.220
Phenols	10	0.135	0.079

Table 4.6-9 Summary of Phase 2 Nontarget VOC Detections in Tenax-and-Charcoal Media ($\mu\text{g}/\text{m}^3$)

Compound	No. of Detections	24-Hour Maximum	Mean
Aldehydes	15	0.146	0.071
Alkanes	476	5.776	1.150
Alkenes	41	4.590	0.701
Benzenes	15	0.201	0.075
Cyclic alkanes	41	2.635	1.106
Cyclic alkenes	10	0.209	0.090
Cyclohexanes	115	1.973	0.360
Freons	37	5.843	0.947
Ketones	37	1.950	0.368
Methyl benzoate	1	0.034	0.034
Naphthalenes	2	0.153	0.096
Oxygenated hydrocarbons	4	3.607	2.392
Phenols	7	0.088	0.063
Terpenes	3	0.112	0.090
Unknowns	20	3.333	1.827

Table 4.6-10 Summary of Phase 3 Nontarget VOC Detections in Tenax-and-Charcoal Media ($\mu\text{g}/\text{m}^3$)

Compound	No. of Detections	24-Hour Maximum	Mean
Aldehydes	23	0.242	0.078
Alkanes	325	3.788	0.927
Alkenes	31	1.068	0.214
Alkynes	1	0.287	0.287
Benzenes	4	0.171	0.097
Benzoic acid hydrazide	1	0.036	0.036
Benzoyl chloride	1	0.069	0.069
Carenes	1	0.071	0.071
Cyclic alkanes	36	0.725	0.295
Cyclic alkenes	4	0.358	0.214
Cyclic hydrocarbons	2	0.074	0.055
Cyclic ketones	2	0.364	0.327
Cyclohexanes	53	2.740	0.235
Esters	6	1.068	0.322
Ethyl acetate	5	0.343	0.201
Freons	15	2.788	1.145
Ketones	29	1.071	0.216
Naphthalenes	4	0.145	0.071
Oxygenated hydrocarbons	16	0.727	0.273
Phenols	7	0.727	0.161
Silanes	11	0.242	0.113
Terpenes	3	0.151	0.112
Tetrahydrofurans	2	1.779	1.437

Table 4.6-11 Summary of Phase 4 Nontarget VOC Detections in Tenax-and-Charcoal Media ($\mu\text{g}/\text{m}^3$)

Compound	No. of Detections	24-Hour Maximum	Mean
Aldehydes	6	0.355	0.249
Alkanes	106	7.092	0.552
Carenes	1	0.697	0.697
Cyclic alkanes	2	0.069	0.053
Cyclohexanes	1	0.139	0.139
Freons	16	3.484	0.533
Ketones	7	1.064	0.272
Methyl t-butyl ether	1	1.418	1.418
Oxygenated hydrocarbons	21	1.056	0.166
Terpenes	1	0.069	0.069
Unknowns	2	0.355	0.195

Table 4.6-12 Summary of Phase 1 Coeluting Nontarget VOC Detections in Tenax Media ($\mu\text{g}/\text{m}^3$)

Compound	No. of Detections	24-Hour Maximum	Mean
Aliphatic hydrocarbon + benzene	9	0.478	0.277
Alkane + alkene	1	0.090	0.090
Alkane + chlorofluorocarbon	3	1.014	0.489
Alkane + phenol	1	0.221	0.221
Aniline + aliphatic hydrocarbon	1	0.314	0.314
C11 alkane + benzonitrile	2	0.641	0.555
C4 benzene + C4 alkenyl benzene	6	0.211	0.122
C4 benzene + column bleed	1	0.478	0.478
C4 benzene + phenol	4	0.814	0.526
C5 alkane + acetic acid	1	0.044	0.044
Cyclopentadiene + acetone	2	0.264	0.214
Hexachlorobutadiene + naphthalene	2	0.076	0.072

Table 4.6-13 Summary of Phase 2 Coeluting Nontarget VOC Detections in Tenax Media ($\mu\text{g}/\text{m}^3$)

Compound	No. of Detections	24-Hour Maximum	Mean
Aliphatic hydrocarbon + benzene	44	1.579	0.438
Aliphatic hydrocarbon + column bleed	7	0.559	0.353
Alkane + alkene	4	1.233	0.672
Alkane + benzene	30	1.419	0.420
Alkane + chlorofluorocarbon	6	4.561	2.902
Alkane + phenol	5	1.505	0.301
Benzaldehyde + C3 benzene	1	1.573	1.573
Benzonitrile + aliphatic hydrocarbon	1	0.083	0.083
C3 benzene + benzonitrile	3	1.839	1.462
C3 benzene + benzonitrile + aliphatic hydrocarbon	1	0.223	0.223
C4 benzene + c4 alkenyl benzene	22	0.627	0.185
C4 benzene + column bleed	18	2.091	0.876
C4 benzene + phenol	2	0.326	0.229
C6 alkane + 2nd cpd (m/z 73)	2	2.691	2.626
Methyl naphthalene + C13 alkane	3	0.769	0.583

Table 4.6-14 Summary of Phase 3 Coeluting Nontarget VOC Detections in Tenax Media ($\mu\text{g}/\text{m}^3$)

Compound	No. of Detections	24-Hour Maximum	Mean
Aliphatic hydrocarbon + benzene	14	0.227	0.118
Aliphatic hydrocarbon + methyl phenol	1	0.036	0.036
Aliphatic hydrocarbon + unknown	1	0.036	0.036
Alkane + benzene	3	1.091	0.639
Alkane + phenol	7	0.717	0.324
Benzene + unknown	6	0.182	0.120
C10 cycloalkene + C4 benzene	1	0.069	0.069
C3 benzene + C7 ketone	1	0.037	0.037
C3 benzene + limonene	1	0.205	0.205
C4 benzene + hydrocarbon	2	0.714	0.411
C4 benzene + phenol	2	0.181	0.162
C4 benzene + silane	2	0.144	0.126
Carene + aliphatic hydrocarbon	1	0.166	0.166
Ethyl acetate + aliphatic hydrocarbon	1	0.036	0.036
Ethyl butanoate + silane	1	0.036	0.036
Oxygenated hydrocarbon + silane compound	1	0.177	0.177

Table 4.6-15 Summary of Phase 4 Coeluting Nontarget VOC Detections in Tenax Media ($\mu\text{g}/\text{m}^3$)

Compound	No. of Detections	24-Hour Maximum	Mean
C9 alkane + C10 alkane	2	0.071	0.071

Table 4.6-16 Summary of Phase 1 Coeluting Nontarget VOC Detections in Tenax-and-Charcoal Media ($\mu\text{g}/\text{m}^3$)

Compound	No. of Detections	24-Hour Maximum	Mean
Aliphatic hydrocarbon + benzene	1	0.043	0.043
Alkane + alkene	6	6.143	3.608
Alkane + chlorofluorocarbon	5	2.962	1.797
Aniline + aliphatic hydrocarbon	1	0.047	0.047
C6 alkane + unknown silane (m/z 73)	1	1.538	1.538
Chlorofluorocarbon + 1,1-dichloroethylene	6	0.676	0.317
Chlorofluorocarbon + dichloroethylene	3	0.151	0.133

Table 4.6-17 Summary of Phase 2 Coeluting Nontarget VOC Detections in Tenax-and-charcoal Media ($\mu\text{g}/\text{m}^3$)

Compound	No. of Detections	24-Hour Maximum	Mean
Aliphatic hydrocarbon + benzene	3	0.075	0.051
Aliphatic hydrocarbon + column bleed	4	0.544	0.347
Alkane + alkene	25	9.386	4.101
Alkane + chlorofluorocarbon	9	11.070	4.832
Alkane + phenol	5	0.255	0.117
C6 alkane (+ Ch_2Cl_2)	1	2.365	2.365
C6 alkane + 2nd cpd (m/z 73)	2	3.413	3.027
C6 alkane + column bleed	2	4.000	3.224
Chlorofluorocarbon + 1,1-dichloroethylene	3	0.121	0.162
Chlorofluorocarbon + acetone	6	2.615	1.098
Chlorofluorocarbon + dichloroethylene + aliphatic HC	1	0.059	0.059
Cyclohexane + column bleed	2	0.058	0.050
Naphthalene + aliphatic hydrocarbon	1	0.043	0.043
Naphthalene + column bleed	1	0.046	0.046
Phenol + 2nd compound	1	0.052	0.052
Trichlorotrifluoroethane + aliphatic hydrocarbon	1	0.557	0.557
Trichlorotrifluoroethane + oxygenated compound	1	0.816	0.816

Table 4.6-18 Summary of Phase 3 Coeluting Nontarget VOC Detections in Tenax-and-Charcoal Media ($\mu\text{g}/\text{m}^3$)

Compound	No. of Detections	24-Hour Maximum	Mean
Aliphatic HC + benzaldehyde	1	0.033	0.033
C8 alkane + unknown (m/z 88)	1	0.070	0.070
Dichlorotetrafluoroethane + C4 alkane	1	0.247	0.247
Trichlorotrifluoroethane + acetone	5	0.738	0.421

Table 4.6-19 Summary of Phase 4 Coeluting Nontarget VOC Detections in Tenax-and-Charcoal Media ($\mu\text{g}/\text{m}^3$)

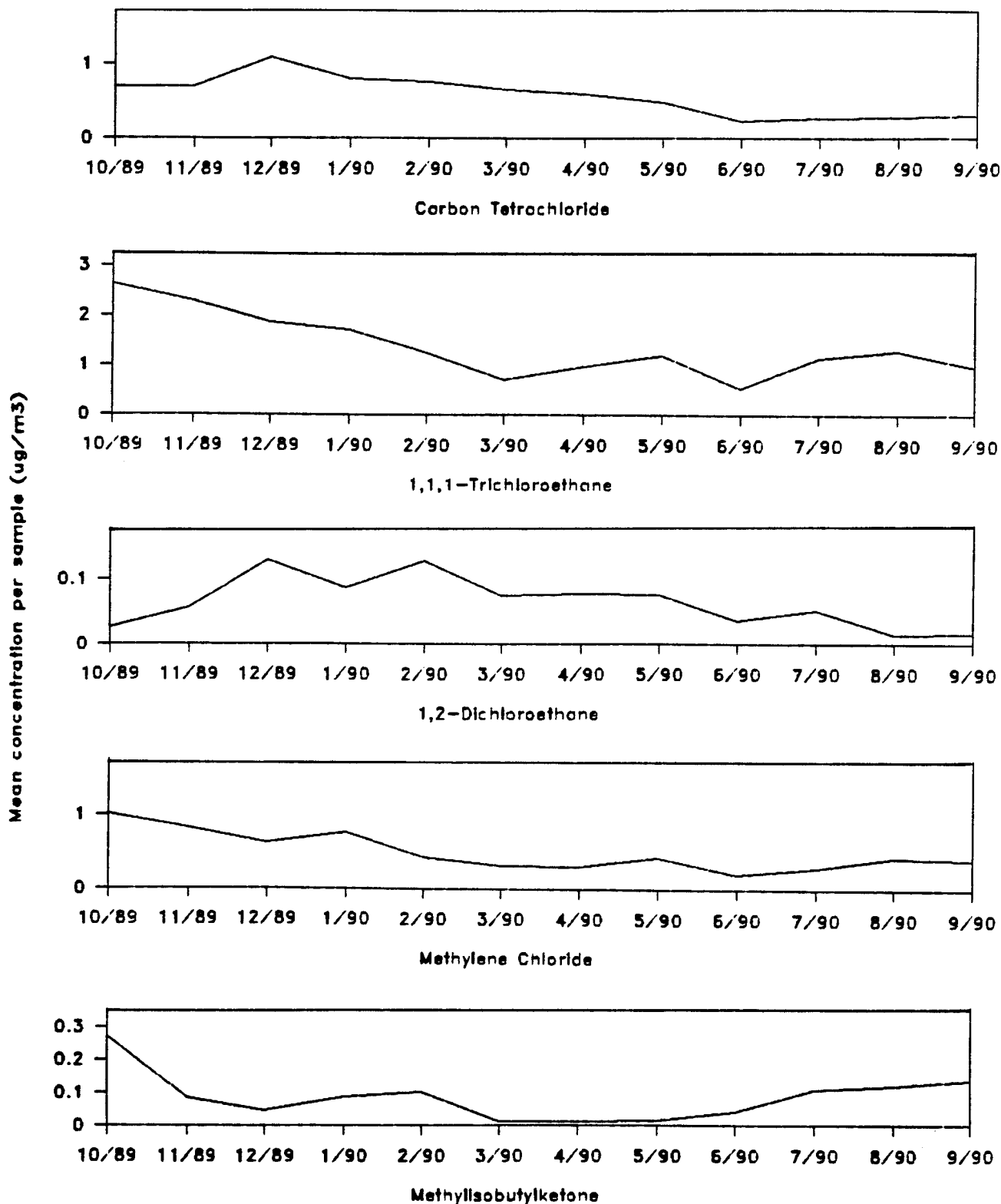
Compound	No. of Detections	24-Hour Maximum	Mean
Isopropanol + C5 hydrocarbon	2	0.355	0.212

4.6.7 Annual Cycle in Volatile Organic Compounds Concentrations

The emission of VOCs is, by its very nature, dependent upon the temperature of the compound, wind speed and other features such as moisture and snow cover. In addition, meteorological conditions of dispersion and diffusion play a very important role in determining ambient concentrations of any pollutant emitted into the atmosphere. With these considerations, and given the strong annual cycle in meteorological conditions in the Denver metropolitan area, there is likely to be a corresponding annual cycle in VOC concentrations as well.

At RMA, VOC emissions have been caused by remedial activity and final capping of the Basin F floor and waste pile. These activities would mask a natural annual cycle. During Phase 4, however, there were no major remedial activities, and the sampled concentrations should reflect the natural annual cycle in VOC emissions and atmospheric dispersion following remediation. The Denver metropolitan area is the source of VOCs emitted by the industrial activity and traffic. For these compounds, maximum ambient concentrations are likely to occur during the winter months, when atmospheric dispersion is relatively poor. The VOCs that were emitted by Basin F, or other sources at the surface of the earth, were likely to be very responsive to the mean temperature conditions. As a result, maximum emissions occurred during the summer months. However, since atmospheric dispersion was strongest during the summer months and poorest during the winter months, the annual cycle in atmospheric concentrations of Basin F emissions was sensitive to two strong, competing influences.

The mean monthly concentrations for all VOC samples collected during the IRA-F program (excluding the collocated samples), for each month of Phase 4 are shown in Figures 4.6-19a through 4.6-19c. Not all target VOCs are shown here, because many had very few or no detections above the CRL and would not exhibit a meaningful annual cycle. As was noted above, several target VOCs were emitted by the Denver metropolitan area, including benzene, toluene, xylenes, ethylbenzene, tetrachloroethylene, trichloroethylene, carbon tetrachloride, 111TCE, 12DCLE, and methylene chloride. The annual cycle for these compounds shows a maximum level during the late fall and winter months, and a minimum level during the summer



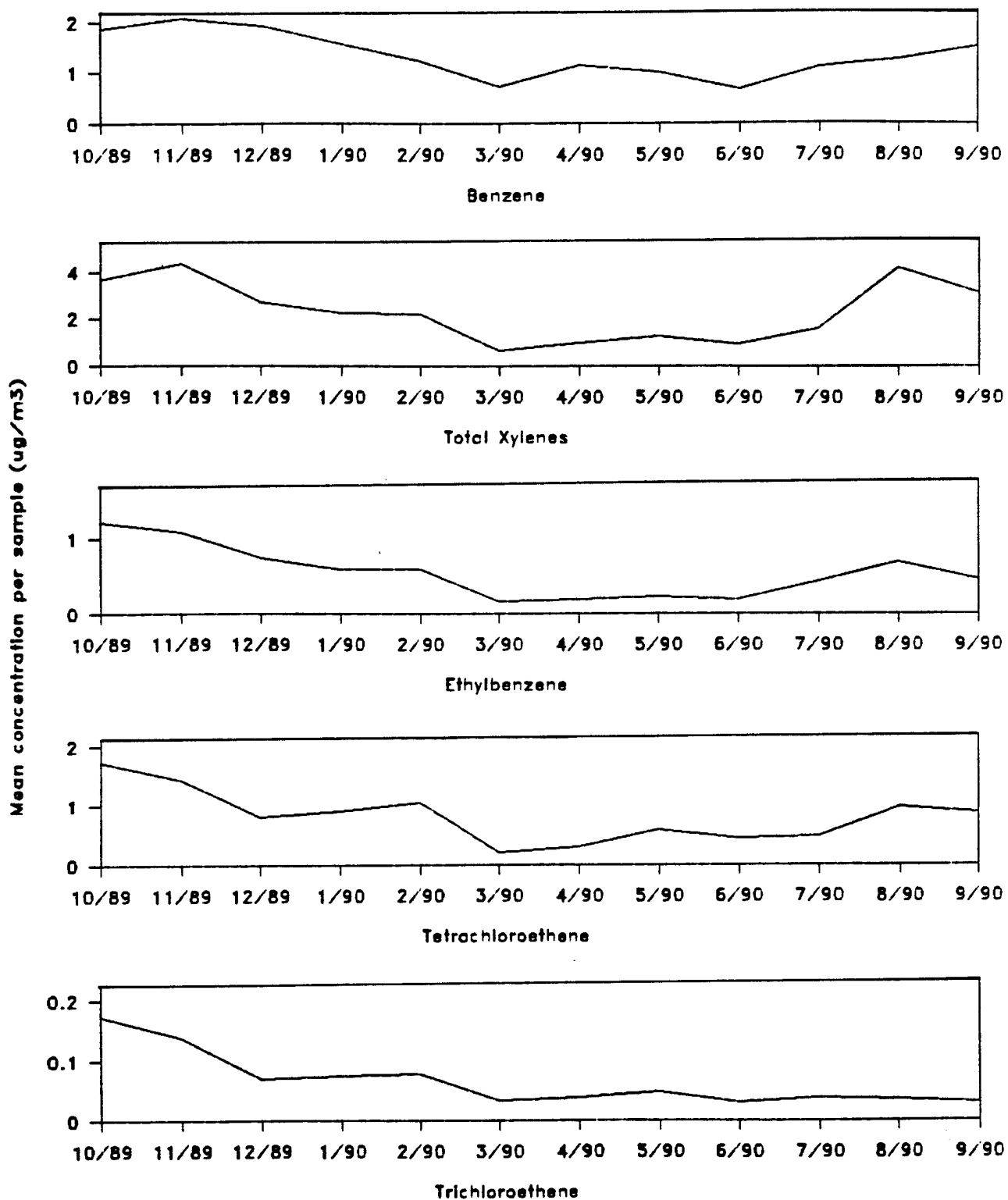
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Figure 4.6-19a

**Mean Monthly VOC Concentrations for
Phase 4 (FY90)**

Note: Different Scales



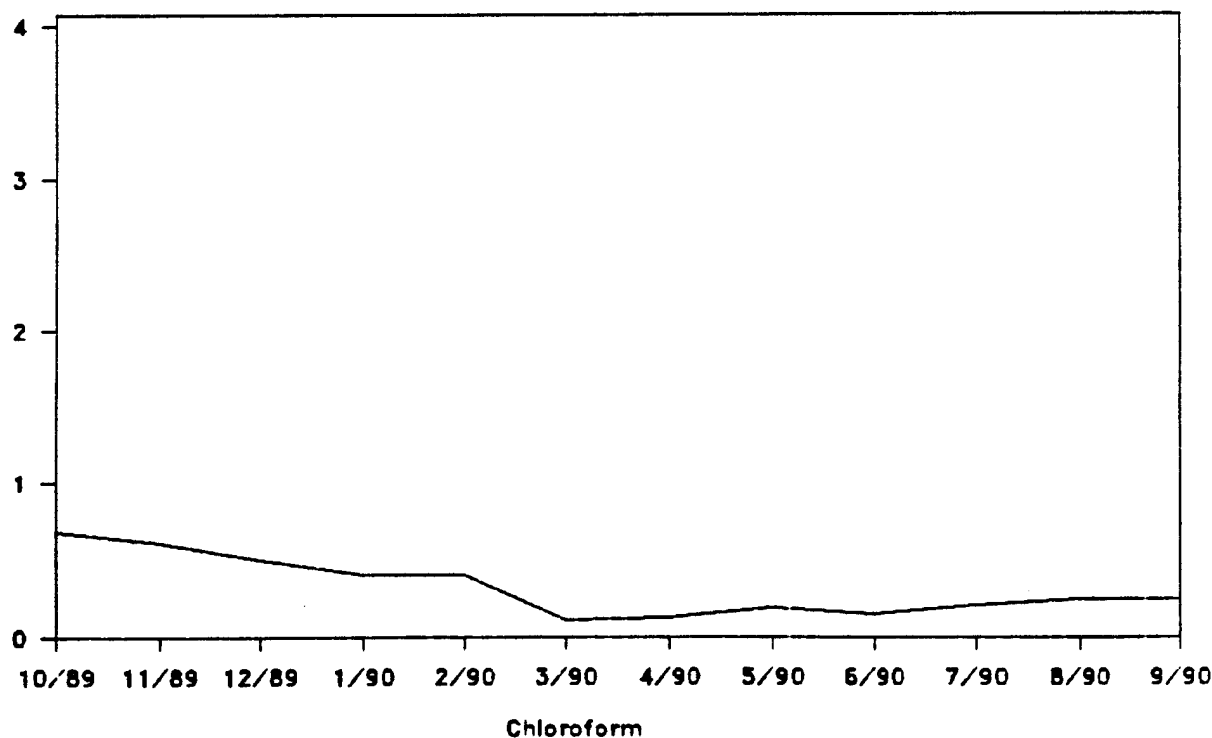
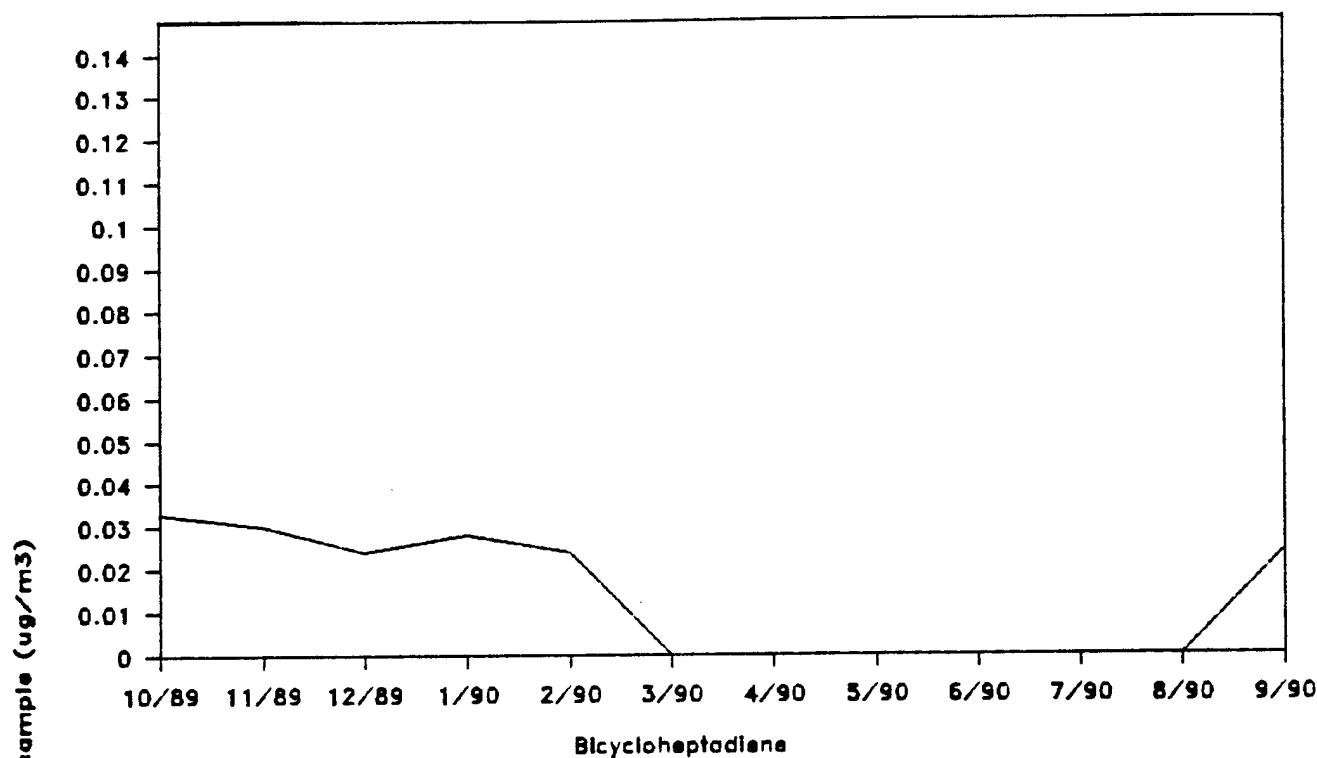
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Figure 4.6-19b

**Mean Monthly VOC Concentrations for
Phase 4 (FY90)**

Note: Different Scales



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Figure 4.6-19c

Mean Monthly VOC Concentrations for
Phase 4 (FY90)

Note: Different Scales

months, when dispersion conditions were best and concentrations were lower. The similarity of the cycles for these compounds, is shown in Figures 4.6-19a and 4.6-19b.

The VOCs that were likely to be emitted from the Basin F area included chloroform and BCHPD. The annual cycle for these compounds, illustrated in Figure 4.6-19c show a cycle with highest levels during the fall and winter. This pattern shows a dominant influence of atmospheric dispersion conditions on ambient concentrations of potential emissions from the former Basin F.

Bicycloheptadiene was detected most often at FC-2 (and FC-2D) during Phase 4. Other sites show very few or no detections. The annual cycle in Figure 4.6-19c shows the maximum concentrations during the winter and the minimum in the summer. Clearly, this compound was being emitted from the former Basin F, and its emissions may not have been as temperature-sensitive as other VOCs. In addition, the wetter spring months (May and June) had the lowest concentrations, indicating that the BCHPD emissions may be sensitive to soil moisture.

Chloroform is one of the better indicator compounds for emissions from the former Basin F, and its annual cycle of average concentrations clearly shows a maximum in winter and a minimum in summer. For this compound, it is clear that atmospheric emission was continual throughout the year and that atmospheric dispersion conditions at RMA governed ambient concentrations.

The annual cycles described above tend to support the conclusions regarding potential sources for the VOCs. For compounds that had a clear source at the former Basin F, the greatest average ambient impacts tended to occur in winter. This pattern developed because the annual cycle in dispersion conditions in the atmosphere is stronger than the annual cycle of emissions, which are in turn related to temperature. The net effect was that although emissions were greater with higher temperatures, the poor dispersion conditions during the winter caused the concentrations to build to higher levels near Basin F. Maximum concentrations, even for sources at Basin F, are likely to occur in late fall or winter months, because the atmospheric dispersion conditions are poorest.

4.7 SEMIVOLATILE ORGANIC COMPOUNDS AND ORGANOCHLORINE PESTICIDES

Semivolatile organic compounds include those compounds with higher boiling points, or lower volatility, than the VOCs. Target SVOCs included seven organochlorine pesticides (OCPs) and six other compounds. As was noted in Section 3.6, the basic SVOC analytical method included a broader range of target compounds than the OCP method. In addition, the SVOC analytical method (GC/MS) also allowed the analysis for nontarget compounds. The results of both analyses are reported together in this section for two reasons: (1) the same OCP target analytes were included in both methods, and (2) the SVOC method provided a minimal number of detections of target analytes. The LCRL for the pesticides under the OCP method was about 100 times lower, or more sensitive, than the LCRL under the SVOC method. As a result there were numerous detections of the OCPs with the GC/ECD method, and very few detections with the GC/MS method. It is also important to note that during the IRA-F monitoring period, the laboratory's SVOC analytical method was modified somewhat, and one compound was dropped from the target list because the method was less sensitive to it. The detection limits for all compounds also changed.

4.7.1 Recovery of Semivolatile Organic Compounds and Organochlorine Pesticides Samples

The recovery percentages for IRA-F SVOC and OCP samples are summarized in Table 4.7-1. Because SVOCs and OCPs were analyzed from the same sample the number of samples recovered during IRA-F was identical. However, the number of valid samples for each class can vary, since they were analyzed under different methods. The low recoveries obtained for SVOCs were due primarily to extensive periods of time during which the laboratory's analytical method was out of certification or was judged to be "out of control" by a subsequent review of control charts. Very few OCPs were lost due to method decertification.

4.7.2 Mean Semivolatile Organic Compounds and Organochlorine Pesticides Concentrations

Mean concentrations of OCPs and SVOCs are presented in Tables 4.7-2 and 4.7-3, respectively. Four OCP analytes were detected throughout all phases (Aldrin, Dieldrin, Endrin, and Isodrin). The OCP results show that the highest levels occurred during Phase 1, as expected.

Table 4.7-1 Recovery of IRA-F Semivolatile Organic Compounds/Organochlorine Pesticides Samples

STATION	NUMBER OF SAMPLES IN PERIOD	NUMBER OF VALID SAMPLES		RECOVERY PERCENT	
		SVOC	OCP	SVOC	OCP
FC-1	85	52	72	61.2	84.7
FC-2	85	54	74	63.5	87.1
FC-2D	43	27	37	62.8	86
FC-3	85	53	74	62.4	87.1
FC-4	85	54	74	63.5	87.1
FC-5	79	50	71	63.3	89.9
BF-5	9	6	6	66.7	66.7
BF-7	9	6	6	66.7	66.7
RIFS1	9	6	6	66.7	66.7
All Stations	489	308	420	62.9	85.9

Table 4.7-2 Arithmetic Mean Organochlorine Pesticides Concentrations ($\mu\text{g}/\text{m}^3$) at Basin F, RIFS and IRA-F Sampling Locations

	ALDRN	CLDAN	DLDRN	ENDRN	ISODR	ppDDE	ppDDT
Phase 1 (3/22/88 - 12/12/88)							
BF-1	0.1913	ND*	0.1408	0.0719	0.0076	ND	ND
BF-2	0.4579	ND	0.2768	0.1209	0.0424	ND	ND
BF-2C	0.5263	ND	0.2475	0.1142	0.0584	ND	ND
BF-3	0.0662	ND	0.0808	0.0250	0.0017	ND	ND
BF-4	0.0499	ND	0.0477	0.0234	0.0030	ND	ND
BF-5	0.0221	ND	0.0193	0.0096	0.0011	ND	ND
BF-6	0.0058	ND	0.0083	0.0031	0.0004	ND	ND
BF-7	0.0016	ND	0.0038	0.0011	0.0003	ND	0.0008
Phase 2 - Stage 1 (12/13/88 - 2/15/89)							
BF-1	0.0106	ND	0.0075	0.0041	0.0013	ND	ND
BF-2	0.0154	ND	0.0107	0.0044	0.0010	ND	ND
BF-2C	0.0071	0.0071	0.0079	0.0047	0.0008	0.0013	0.0007
BF-3	0.0026	ND	0.0032	0.0017	0.0005	ND	ND
BF-4	0.0034	ND	0.0027	0.0014	0.0007	ND	ND
BF-5	0.0010	ND	0.0010	0.0008	ND	ND	ND
BF-6	0.0006	ND	0.0012	0.0011	0.0003	0.0007	ND
BF-7	ND	ND	0.0008	0.0007	ND	ND	ND
Phase 2 - Stage 2 (2/16/89 - 5/5/89)							
BF-1	0.0023	ND	0.0057	0.0024	0.0003	ND	ND
BF-2	0.0022	ND	0.0076	0.0019	ND	ND	ND
BF-2C	0.0017	ND	0.0077	0.0023	ND	0.0007	ND
BF-3	0.0006	ND	0.0031	0.0010	ND	ND	ND
BF-4	0.0007	ND	0.0020	0.0010	ND	ND	ND
BF-5	0.0005	ND	0.0011	0.0007	ND	ND	ND
BF-6	0.0004	ND	0.0015	0.0008	ND	ND	ND
BF-7	ND	ND	0.0009	ND	ND	ND	ND
RIFS1	ND	0.0003	0.0003	ND	ND	ND	0.0002
RIFS1D	ND	0.0003	0.0005	ND	ND	ND	ND
Phase 3 (5/6/89 - 9/30/89)							
FC-1	0.0006	0.0004	0.0047	0.0006	0.0002	ND	ND
FC-2	0.0014	0.0006	0.0121	0.0013	0.0004	ND	0.0003
FC-2D	0.0016	0.0005	0.0130	0.0013	0.0014	ND	0.0002
BF-3/FC-3	0.0004	0.0005	0.0074	0.0006	0.0003	ND	0.0002
BF-4/FC-4	0.0005	0.0004	0.0061	0.0007	0.0002	ND	ND
BF-5	0.0002	0.0002	0.0015	0.0003	ND	ND	ND
FC-5	0.0006	0.0003	0.0032	0.0003	ND	ND	ND
BF-7	0.0002	0.0004	0.0024	0.0004	0.0002	ND	ND
RIFS1	ND	0.0003	0.0012	0.0002	ND	ND	ND
Phase 4 (10/1/89 - 9/30/90)							
FC-1	0.0005	0.0003	0.0035	0.0004	0.0002	ND	0.0002
FC-2	0.0012	0.0004	0.0087	0.0009	0.0002	ND	0.0004
FC-2D	0.0018	0.0003	0.0098	0.0010	0.0002	ND	0.0004
FC-3	0.0004	0.0003	0.0035	0.0004	0.0002	0.0002	0.0003
FC-4	0.0007	0.0003	0.0053	0.0005	0.0002	ND	0.0002
FC-5	0.0005	0.0003	0.0030	0.0005	0.0002	ND	0.0002

* ND = Not Detected

ALDRN = Aldrin

CLDAN = Chlordane

DLDRN = Dieldrin

ENDRN = Endrin

ISODR = Isodrin

ppDDE = p,p'-dichlorodiphenylethane

ppDDT = p,p'-dichlorodiphenyltrichloroethane

Table 4.7-3 Arithmetic Mean SVOC Concentrations ($\mu\text{g}/\text{m}^3$) at Basin F, RIFS and IRA-F Sampling Locations

	ATZ	CLDAN	CPMSO	CPMSO2	DLDRN	ENDRN	ISODR	MLTHN	ppDDE	ppDDT	PRTN	SUPONA
Phase 1 (3/22/88 - 12/12/88)												
BF-1	ND*	ND	N/A**	N/A	ND	ND	ND	ND	ND	ND	ND	ND
BF-2	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
BF-2C	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
BF-3	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
BF-4	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
BF-5	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
BF-6	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
BF-7	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
RIFS1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phase 2 - Stage 1 (12/13/88 - 2/15/89)												
BF-1	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
BF-2	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
BF-2C	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
BF-3	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
BF-4	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
BF-5	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
BF-6	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
BF-7	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
RIFS1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RIFS1D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RIFS2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phase 2 - Stage 2 (2/16/89 - 5/5/89)												
BF-1	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
BF-2	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
BF-2C	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
BF-3	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
BF-4	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
BF-5	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
BF-6	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
BF-7	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
RIFS1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RIFS1D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RIFS2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phase 3 (5/6/89 - 9/30/89)												
FC-1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
FC-2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
FC-2D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BF-3/FC-3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BF-4/FC-4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BF-5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
FC-5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BF-7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RIFS1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phase 4 (10/1/89 - 9/30/90)												
FC-1	ND	ND	ND	0.0260	0.0115	ND	ND	ND	ND	ND	ND	ND
FC-2	ND	ND	ND	ND	0.0173	ND	ND	ND	ND	ND	ND	ND
FC-2D	ND	ND	ND	ND	0.0203	ND	ND	ND	ND	ND	ND	ND
FC-3	ND	ND	ND	ND	0.0114	ND	ND	ND	ND	ND	ND	ND
FC-4	ND	ND	ND	ND	0.0143	ND	ND	ND	ND	ND	ND	ND
FC-5	ND	ND	ND	0.0288	0.0117	ND	ND	ND	ND	ND	ND	ND

* ND - Not Detected

** N/A - Not a target analyte this phase

ATZ = Atrazine CLDAN = Chlordane CPMSO = P-chlorophenylmethyl sulfoxide CPMSO2 = P-chlorophenylmethyl sulfoxide DLDRN = Dieldrin ENDRN = Endrin ISODR = Isodrin MLTHN = Malathion ppDDE = p,p'-dichlorodiphenylethane ppDDT = p,p'-dichlorodiphenyltrichloroethane PRTN = Parathion

Generally the mean concentrations (except Dieldrin) decreased from Phase 2 to Phase 4. Chlordane concentrations increased from below the detection limit in Phases 1 and 2 to slightly above the detection limit in Phases 3 and 4. Two different laboratories were used for sample analysis during the reported period. One laboratory was used during Phases 1 and 2 at the "BF" sampling sites, and another was used for analysis of RIFS samples and for all IRA-F (Phases 3 and 4) samples. In addition, the deliberate selection of worst case episodes may have lead to slightly higher Phase 1 and Phase 2 results. The average concentrations were remarkably consistent despite the change in laboratories and sampling strategy.

As is clearly indicated by Table 4.7-3, there were very few detections of SVOCs. Only Dieldrin and chlorophenyl methylsulfone were detected, and only in Phase 4. A change in laboratory analysis method certification during Phase 4, which resulted in lowering the detection limit of these compounds, may in part account for the absence of detection prior to that change. It is clear, however, the compounds were rarely present at detectable levels. The results for Dieldrin under the SVOC method confirm the results of OCP analysis on each day for which levels were above the detection limit. Direct comparison of the mean levels between methods is not very meaningful, since the detection limits differ markedly.

4.7.3 Maximum SVOC and OCP Concentrations

Tables 4.7-4 and 4.7-5 provide 24-hour maximum concentrations of OCPs and SVOCs, respectively. The variations in OCP maxima by phase are similar to the pattern displayed by the mean concentrations. The highest maxima occurred during Phase 1 with lower maxima in the subsequent phases. Again, Dieldrin was the exception, with higher maxima in Phases 3 and 4 than in Phase 2. As illustrated in the tables, there were no SVOCs detected in Phases 1 through 3. Maximum SVOC values for Dieldrin in Phase 4 are similar to the results of OCP analyses and, therefore, serve to confirm these values.

The extreme OCP cases selected from IRA-F monitoring results exhibited relatively high concentrations. These extreme events were also selected based upon certain meteorological

Table 4.7-4 24-Hour Maximum Organochlorine Pesticides Concentrations ($\mu\text{g}/\text{m}^3$)
at Basin F, RIFS and IRA-F Sampling Locations

	ALDRN	CLDAN	DLDRN	ENDRN	ISODR	ppDDE	ppDDT
Phase 1 (3/22/88 - 12/12/88)							
BF-1	0.8366	ND*	0.4904	0.2497	0.0604	ND	ND
BF-2	2.8290	ND	2.2960	0.9020	0.8610	ND	ND
BF-2C	2.5773	ND	2.1478	1.0954	0.9450	ND	ND
BF-3	0.4288	ND	1.6568	0.5458	0.0226	ND	ND
BF-4	0.3478	ND	0.3265	0.2591	0.1136	ND	ND
BF-5	0.1723	ND	0.0499	0.0275	0.0080	ND	ND
BF-6	0.0369	ND	0.0256	0.0093	0.0016	ND	ND
BF-7	0.0124	ND	0.0479	0.0050	0.0007	ND	0.0017
Phase 2 - Stage 1 (12/13/88 - 2/15/89)							
BF-1	0.0830	ND	0.0361	0.0223	0.0114	ND	ND
BF-2	0.1244	ND	0.0355	0.0147	0.0100	ND	ND
BF-2C	0.0210	0.0360	0.0310	0.0130	0.0020	0.0060	0.0010
BF-3	0.0234	ND	0.0130	0.0061	0.0034	ND	ND
BF-4	0.0321	ND	0.0099	0.0042	0.0078	ND	ND
BF-5	0.0080	ND	0.0030	0.0010	ND	ND	ND
BF-6	0.0020	ND	0.0040	0.0040	0.0004	0.0020	ND
BF-7	ND	ND	0.0010	0.0010	ND	ND	ND
Phase 2 - Stage 2 (2/16/89 - 5/5/89)							
BF-1	0.0190	ND	0.0190	0.0070	0.0010	ND	ND
BF-2	0.0230	ND	0.0340	0.0100	ND	ND	ND
BF-2C	0.0090	ND	0.0330	0.0100	ND	0.0010	ND
BF-3	0.0050	ND	0.0110	0.0030	ND	ND	ND
BF-4	0.0040	ND	0.0070	0.0040	ND	ND	ND
BF-5	0.0020	ND	0.0030	0.0010	ND	ND	ND
BF-6	0.0010	ND	0.0050	0.0010	ND	ND	ND
BF-7	ND	ND	0.0017	ND	ND	ND	ND
RIFS1	ND	0.0007	0.0009	ND	ND	ND	0.0007
RIFS1D	ND	0.0006	0.0009	ND	ND	ND	ND
Phase 3 (5/6/89 - 9/30/89)							
FC-1	0.0041	0.0010	0.0188	0.0015	0.0005	ND	ND
FC-2	0.0103	0.0015	0.0444	0.0045	0.0011	ND	0.0010
FC-2D	0.0088	0.0011	0.0424	0.0034	0.0106	ND	0.0006
BF-3/FC-3	0.0017	0.0019	0.0240	0.0021	0.0006	ND	0.0004
BF-4/FC-4	0.0016	0.0014	0.0179	0.0022	0.0005	ND	ND
BF-5	0.0004	0.0005	0.0023	0.0004	ND	ND	ND
FC-5	0.0033	0.0007	0.0159	0.0008	ND	ND	ND
BF-7	0.0004	0.0010	0.0053	0.0006	0.0005	ND	ND
RIFS1	ND	0.0007	0.0033	0.0004	ND	ND	ND
Phase 4 (10/1/89 - 9/30/90)							
FC-1	0.0079	0.0015	0.0310	0.0022	0.0004	ND	0.0006
FC-2	0.0300	0.0023	0.0720	0.0063	0.0011	ND	0.0041
FC-2D	0.0270	0.0015	0.0640	0.0064	0.0005	ND	0.0038
FC-3	0.0035	0.0023	0.0270	0.0039	0.0007	0.0006	0.0014
FC-4	0.0095	0.0014	0.0430	0.0034	0.0004	ND	0.0020
FC-5	0.0073	0.0018	0.0260	0.0067	0.0004	ND	0.0009

* ND = Not Detected

ALDRN = Aldrin

CLDAN = Chlordane

DLDRN = Dieldrin

ENDRN = Endrin

ISODR = Isodrin

ppDDE = p,p'-dichlorodiphenylethane

ppDDT = p,p'-dichlorodiphenyltrichloroethane

Table 4.7-5 24-Hour Maximum SVOC Concentrations ($\mu\text{g}/\text{m}^3$) at Basin F, RIFS and IRA-F Sampling Locations

	ATZ	CLDAN	CPMSO	CPMSO2	DLDRN	ENDRN	ISODR	MLTHN	ppDDE	ppDDT	PRTHN	SUPONA
Phase 1 (3/22/88 - 12/12/88)												
BF-1	ND*	ND	N/A**	N/A	ND	ND	ND	ND	ND	ND	ND	ND
BF-2	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
BF-2C	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
BF-3	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
BF-4	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
BF-5	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
BF-6	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
BF-7	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
RIFS1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phase 2 - Stage 1 (12/13/88 - 2/15/89)												
BF-1	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
BF-2	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
BF-2C	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
BF-3	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
BF-4	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
BF-5	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
BF-6	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
BF-7	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
RIFS1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RIFS1D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RIFS2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phase 2 - Stage 2 (2/16/89 - 5/5/89)												
BF-1	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
BF-2	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
BF-2C	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
BF-3	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
BF-4	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
BF-5	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
BF-6	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
BF-7	ND	ND	N/A	N/A	ND	ND	ND	ND	ND	ND	ND	ND
RIFS1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RIFS1D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RIFS2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phase 3 (5/6/89 - 9/30/89)												
FC-1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
FC-2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
FC-2D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BF-3/FC-3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BF-4/FC-4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BF-5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
FC-5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BF-7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RIFS1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phase 4 (10/1/89 - 9/30/90)												
FC-1	ND	ND	ND	0.0360	0.0210	ND	ND	ND	ND	ND	ND	ND
FC-2	ND	ND	ND	ND	0.0610	ND	ND	ND	ND	ND	ND	ND
FC-2D	ND	ND	ND	ND	0.0590	ND	ND	ND	ND	ND	ND	ND
FC-3	ND	ND	ND	ND	0.0180	ND	ND	ND	ND	ND	ND	ND
FC-4	ND	ND	ND	ND	0.0300	ND	ND	ND	ND	ND	ND	ND
FC-5	ND	ND	ND	0.0840	0.0220	ND	ND	ND	ND	ND	ND	ND

* ND = Not Detected

** N/A = Not a target analyte this phase

ATZ = Atrazine CLDAN = Chlordane CPMSO = P-chlorophenylmethyl sulfoxide CPMSO2 = P-chlorophenylmethyl sulfoxide DLDRN = Dieldrin ENDRN = Endrin ISODR = Isodrin MLTHN = Malathion ppDDE = p,p'-dichlorodiphenylethane ppDDT = p,p'-dichlorodiphenyltrichloroethane PRTHN = Parathion

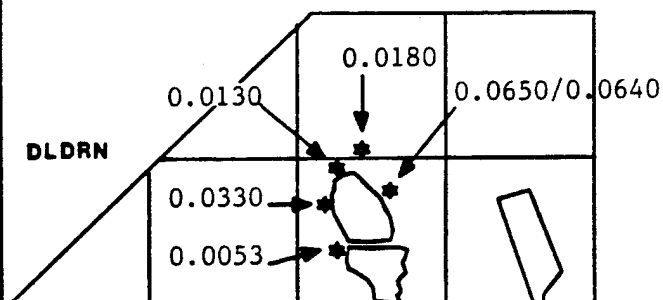
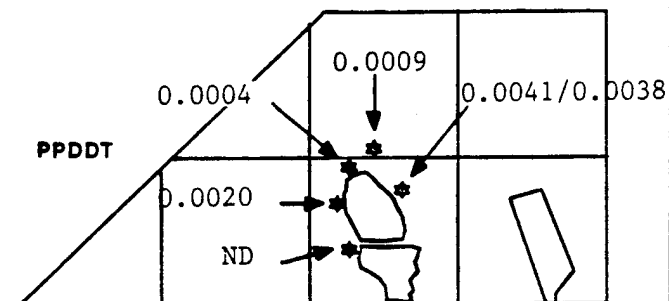
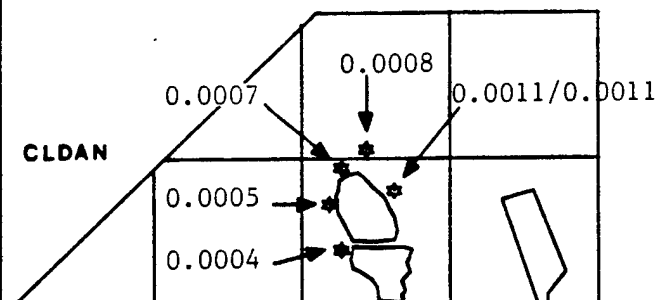
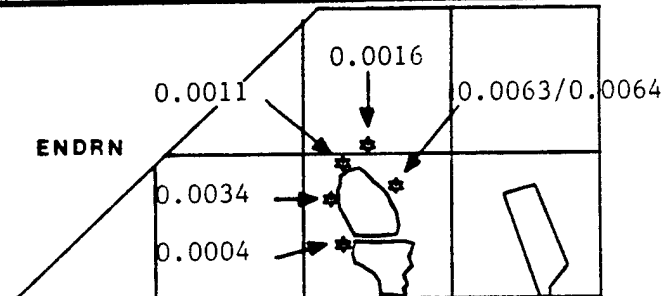
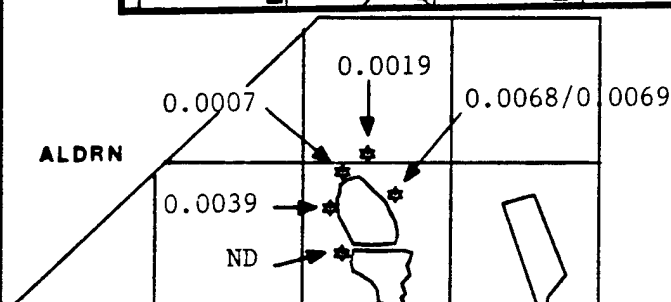
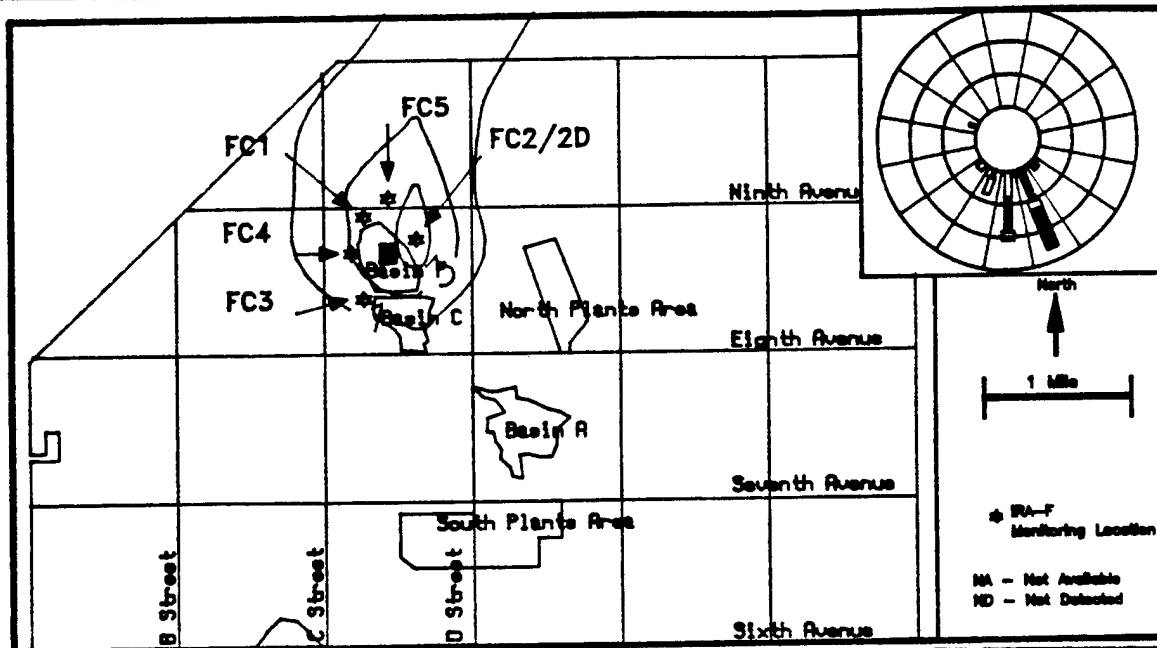
criteria which would contribute to elevated OCP levels. Meteorological conditions which intensified OCP emissions and, therefore, the ambient concentrations of those compounds, were warm temperatures (70°F or warmer), moderate winds and dry ground surface conditions. The results from the selected days were then matched with dispersion patterns for the corresponding 24-hour sampling periods to correlate the sampling results with the theoretical dispersion. Two representative examples of days with elevated OCP concentrations were selected for evaluation.

4.7.3.1 Organochlorine Pesticides High Event: May 29, 1990

Higher than average concentrations of OCPs were present in IRA-F samples collected on this date. Figure 4.7-1 shows the X/Q dispersion pattern, the corresponding wind rose, and the reported OCP concentrations for the sample period (1200 MST on May 28 through 1200 MST on May 29, 1990). Daytime temperatures were mostly in the 60s with a high of 73°F, and a nighttime low of 53°F. Winds were strong to moderate with occasional gusts to 40 mph. During the first 12 hours of the sample period, winds were primarily from the south-southeast, and were sometimes strong. The ground surface was dry since the most recent rainfall of 0.14 inch had occurred 13 days before.

The highest concentrations of all contaminants were recorded at the collocated sites FC-2 and FC-2D. The dispersion pattern illustrated in Figure 4.7-1 indicates that any emissions from the former Basin F would have caused the highest concentration of analytes to impact sampling site FC-2. The closer proximity of FC-4 to the waste pile would help explain why the second highest concentrations were recorded there. Fairly equivalent concentrations were recorded at the remaining sites.

The comparability between the results of the collocated samples was excellent, with the average values from the two samples reported as: Aldrin, 0.0069 $\mu\text{g}/\text{m}^3$; Endrin, 0.0052 $\mu\text{g}/\text{m}^3$; Dieldrin, 0.0645 $\mu\text{g}/\text{m}^3$; Endrin, 0.0064 $\mu\text{g}/\text{m}^3$; and ppDDT, 0.0039 $\mu\text{g}/\text{m}^3$. Site FC-4 showed the next



Prepared for
U.S. Army Program Manager
for Rocky Mountain Arsenal

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5/91

Figure 4.7-1

X/Q Dispersion Pattern, Wind Rose and OCP
Concentrations for May 29, 1990

($\mu\text{g}/\text{m}^3$)

highest concentrations as Aldrin, 0.0039 $\mu\text{g}/\text{m}^3$; Dieldrin, 0.0330 $\mu\text{g}/\text{m}^3$; Endrin, 0.0034 $\mu\text{g}/\text{m}^3$; and ppDDT, 0.0020 $\mu\text{g}/\text{m}^3$. Chlordane was not detected above the LCRL at any site.

The distribution of the actual sampling results within the predicted dispersion for a former Basin F source under the current meteorological conditions confirms that there remains a source of OCPs in the restored Basin F area.

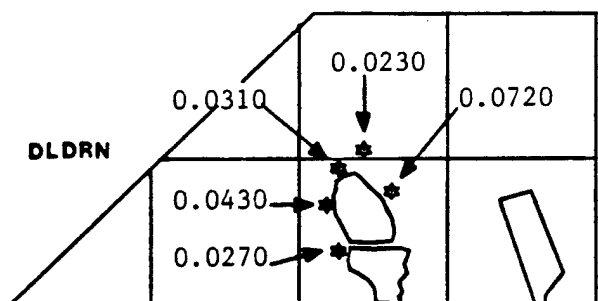
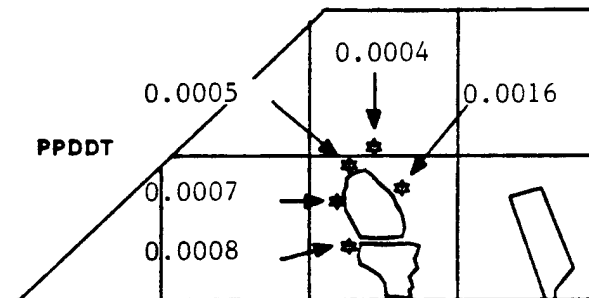
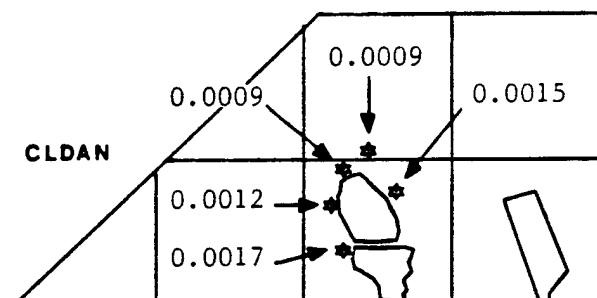
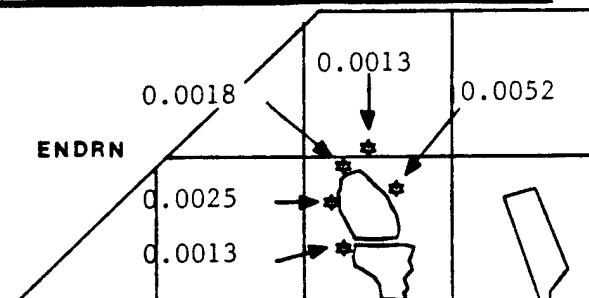
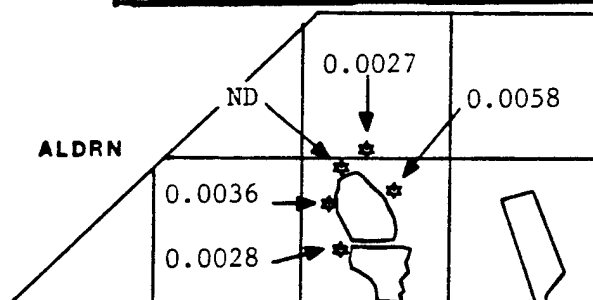
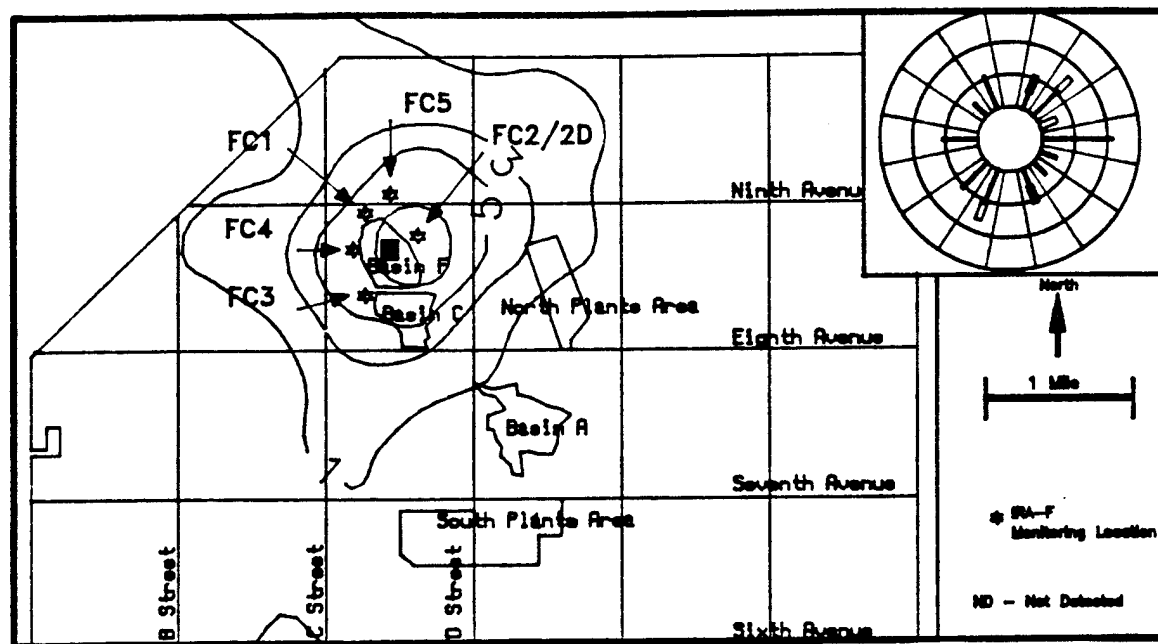
4.7.3.2 Organochlorine Pesticides High Event: July 10, 1990

Samples collected at IRA-F sites on July 10, 1990 exhibited generally high OCP concentrations. Figure 4.7-2 shows the X/Q dispersion pattern, the corresponding wind rose, and the reported IRA-F OCP concentrations for the day (1200 MST on July 9 through 1200 MST on July 10, 1990). Temperatures were in the high 60s to low 70s, with a high of 77°F and an overnight low of 60°F. Winds were light to moderate and variable in direction, coming from all points during the day. The ground surface was slightly moist during most of the sample period, with rain occurring twice during the day, accumulating a total precipitation for the period of 0.64 inch.

The dispersion pattern illustrated in Figure 4.7-2 indicates that FC-2 received the greatest impact from a former Basin F source. Analytical results confirm this situation, with the sample from FC-2 having the highest reported concentrations of most detected target analytes (Aldrin at 0.0058 $\mu\text{g}/\text{m}^3$, Endrin at 0.0052 $\mu\text{g}/\text{m}^3$, Dieldrin at 0.0720 $\mu\text{g}/\text{m}^3$, and ppDDT at 0.0016 $\mu\text{g}/\text{m}^3$). The results from the other sites also confirmed the dispersion pattern. Intermediate concentrations were recorded at FC-1 and FC-4, and the lower concentrations were recorded at FC-3 and FC-5, the more distant or upwind sites. The results of this sampling day appear to verify that a source of OCP emissions appear to exist in the Basin F vicinity.

4.7.4 Analysis of Results for Target Semivolatile Organic Compounds and Organochlorine Pesticides

This section discusses some selected results from the Basin F, IRA-F, and the Odor sampling programs. These results are presented in a graphical format for ease of interpretation and to help



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Figure 4.7-2

X/Q Dispersion Pattern, Wind Rose and OCP
Concentrations for July 10, 1990

($\mu\text{g}/\text{m}^3$)

clarify comparative results. These compounds were also sampled during the RI program of 1987, and under the CMP, which ran concurrently with the reported programs, but has had an RMA-wide focus. Results of these other programs are presented where appropriate to aid interpretation of the results from the Basin F sites.

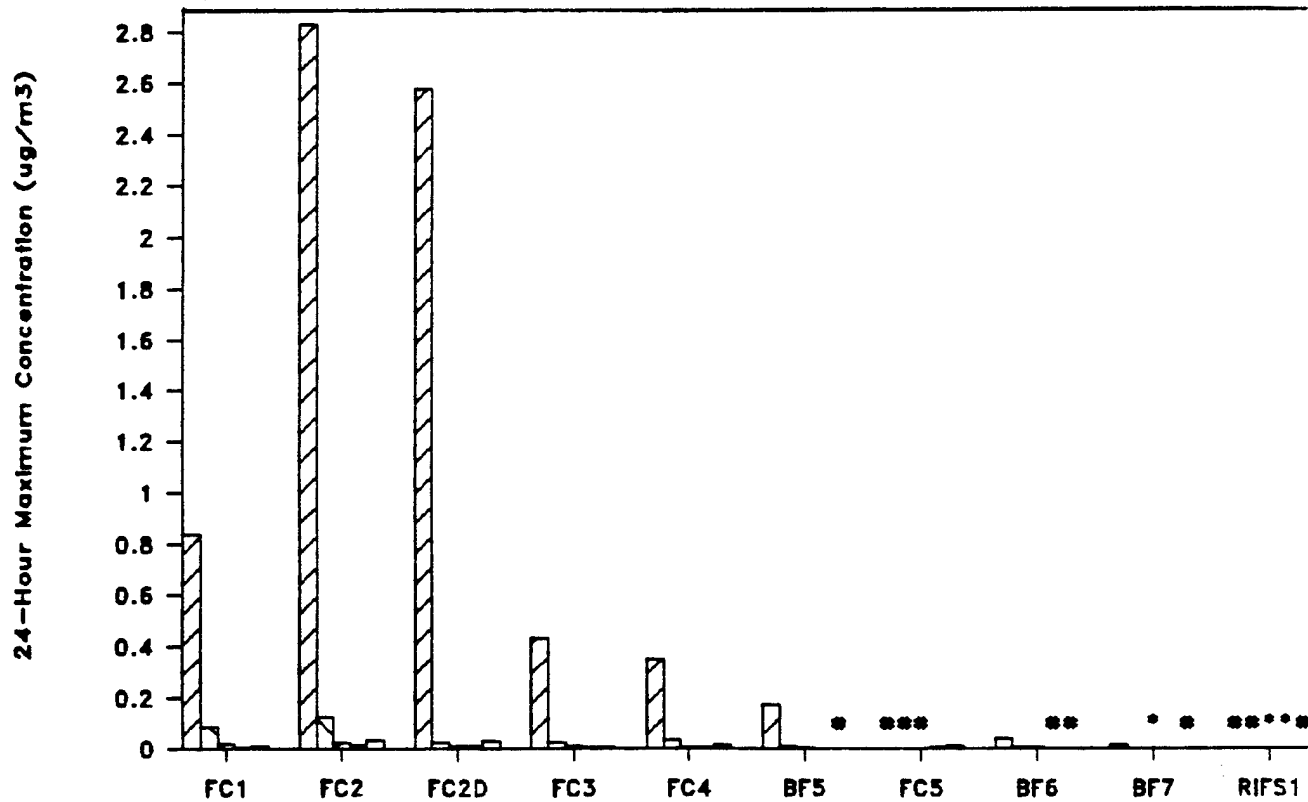
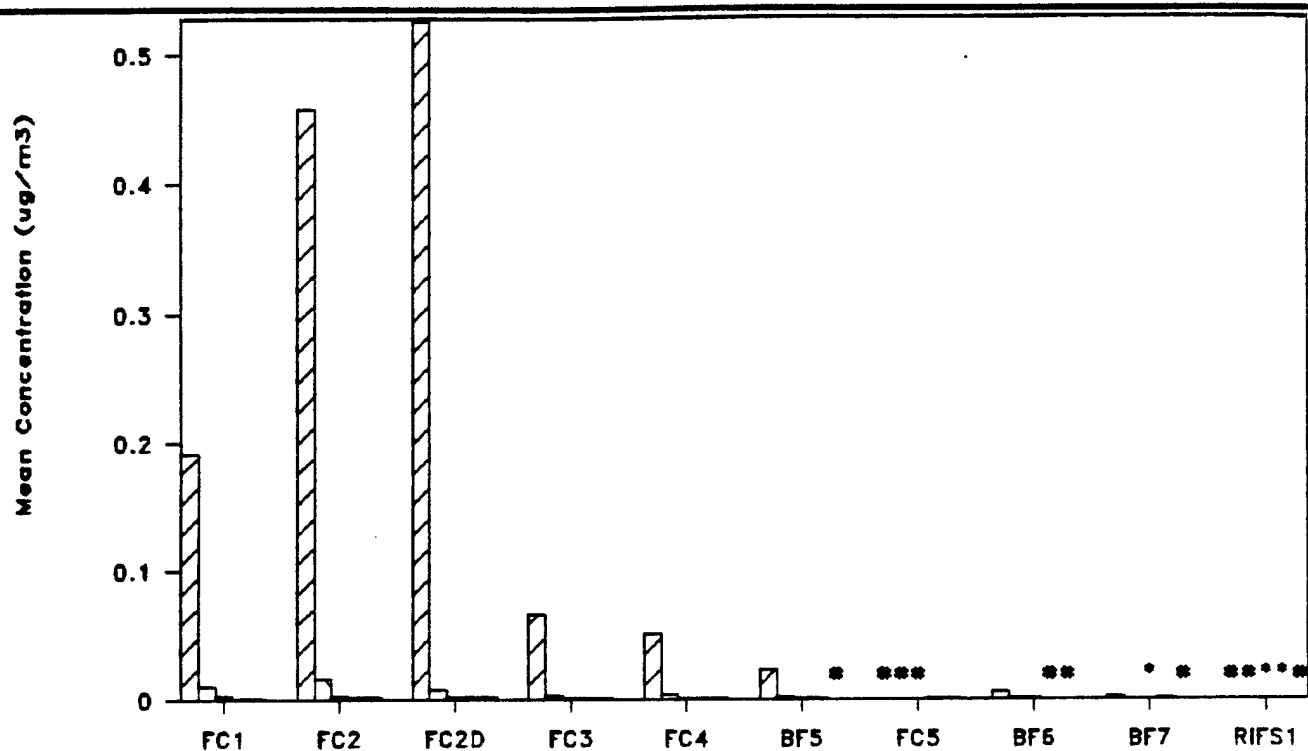
All target OCPs for which important levels of ambient concentrations have been detected are discussed. Other analytes are briefly summarized in the final subsection (4.7.4.6). The mean and extreme values for each analyte are discussed, the sources are analyzed, and other implications of the results are provided.

4.7.4.1 Aldrin

Aldrin was detected in two out of five sampling events during the RI program. Sampling for both of these events centered around Basin F, and included relatively warm summer days. Aldrin levels ranged from 0.064 $\mu\text{g}/\text{m}^3$ to 0.20 $\mu\text{g}/\text{m}^3$ for these events. Results of the sampling programs around Basin F are presented graphically in Figure 4.7-3, which provides both the mean and extreme values by site, for each phase.

In Phase 1, the downwind Basin F sites, BF-2 and BF-2C recorded the highest levels, and BF-1 had the second highest average level. Average Aldrin levels dropped steadily through Phase 2 and into Phase 3, but the highest levels continued to be sampled at the downwind sites. The maximum values in Phase 4 were above those of Phase 3 at all sites around the former Basin F. Levels measured under the CMP during Phase 4, at RMA boundary sites were less than those measured around the former Basin F.

Aldrin results must be interpreted with caution. Of all SVOCs, Aldrin appears to be most volatile, and it evidently either desorbes following adsorption as aeration of the PUF continues, or it breaks down into less volatile constituents. Average recovery rates for Aldrin spikes were in the range of 20 to 30 percent. See Section 5.0 for details of this problem.



P1
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 Site P2-S2
 P3
 P4

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Figure 4.7-3

Mean and Maximum Concentrations for
Aldrin by Site, by Phase

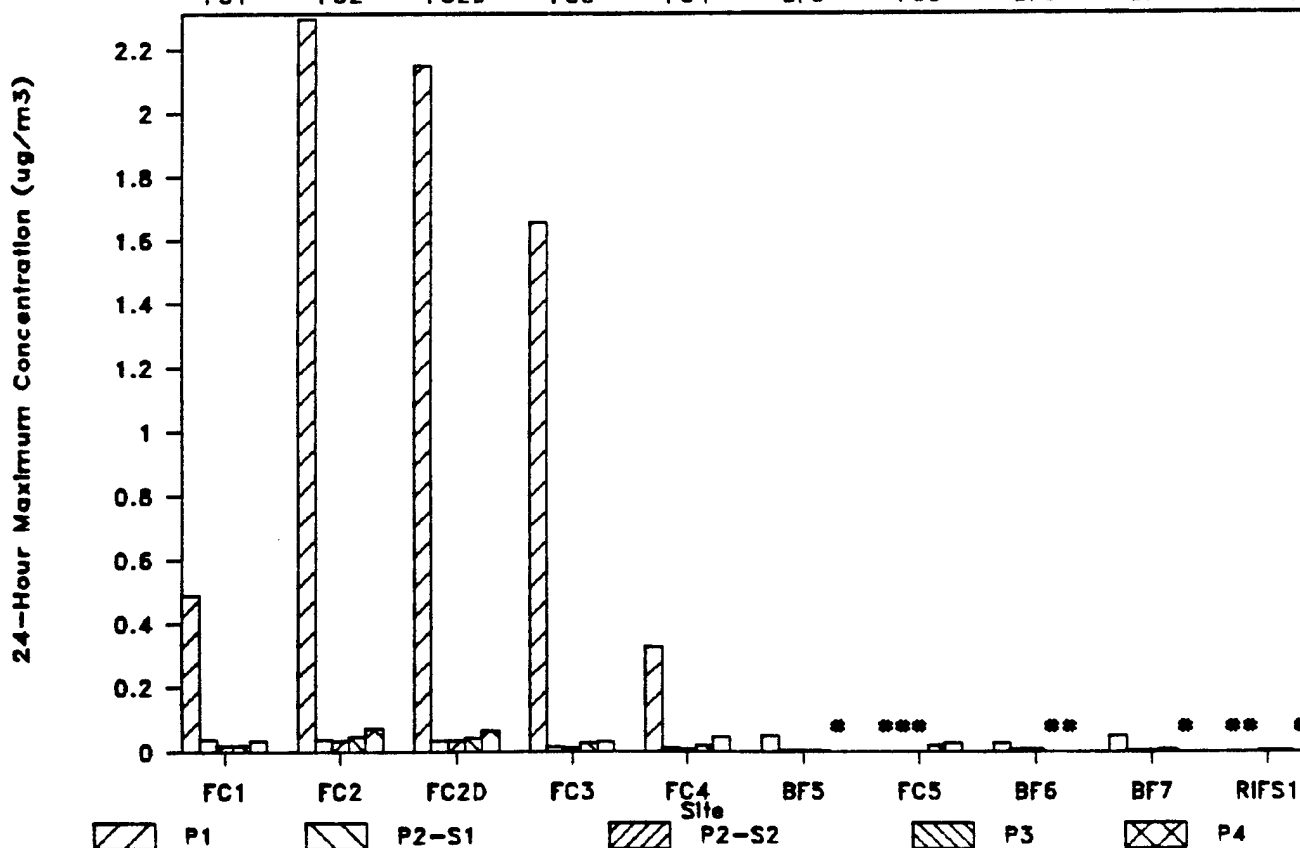
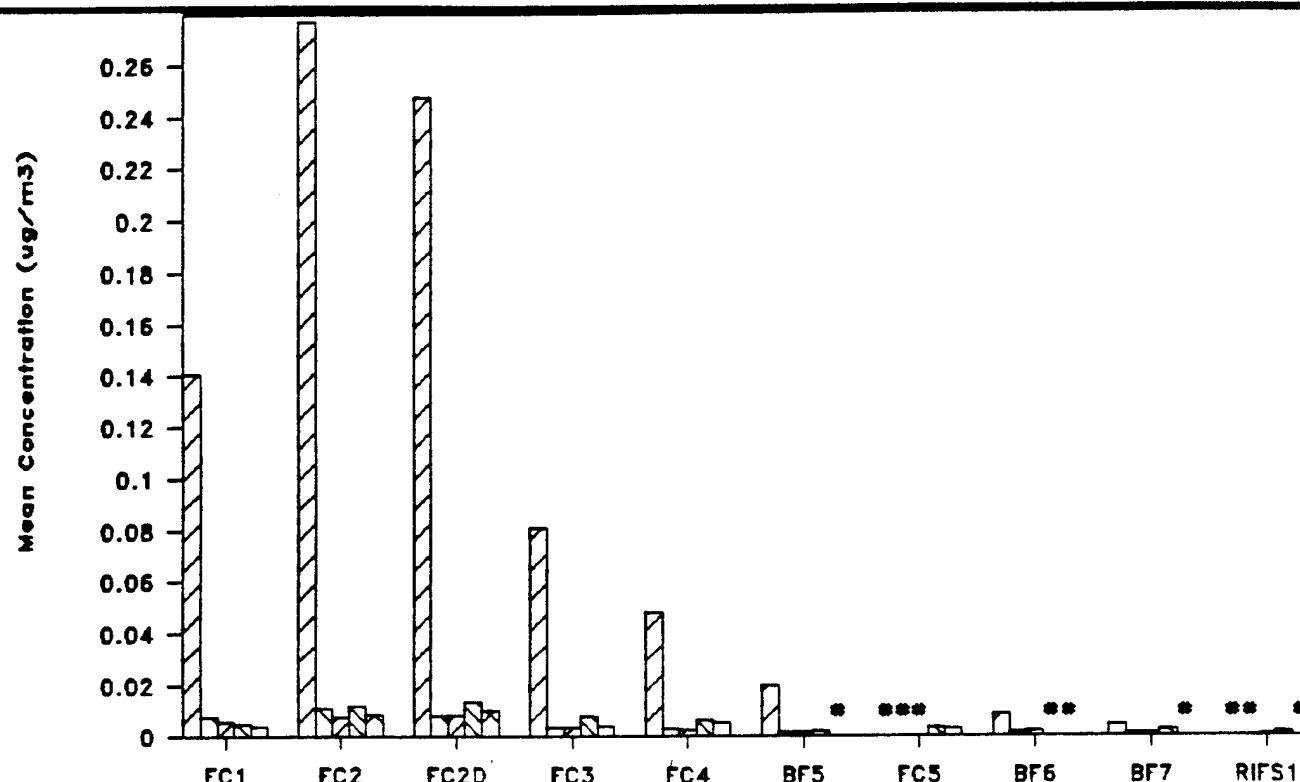
* Not Detected
Not an Analyte This Phase

The mean and extreme values of Aldrin were fairly consistent. Basin F was clearly a source of Aldrin during Phase 1 remedial activities, and evidently remained a source through Phases 2, 3, and 4. There is some evidence that emissions may have been increasing during Phase 4, especially during the summer months.

4.7.4.2 Dieldrin

Dieldrin was sampled during the RI program and was detected in three of five sampling episodes around Basin F during the summer of 1987. Dieldrin concentrations ranged from 0.031 $\mu\text{g}/\text{m}^3$ to 1.6 $\mu\text{g}/\text{m}^3$ during these episodes. The results of the subsequent sampling around Basin F are shown in Figure 4.7-4. A pattern similar to that of Aldrin emerges, with maximum levels in Phase 1 and relative maximum values at the downwind sites during the remaining phases. Average Dieldrin levels during Phase 3 were slightly higher than those of Phase 2, Stage 2 or of Phase 4, but this could be due to the fact that the highest levels tended to occur during the summer months, and Phase 3 essentially spanned the summer months of 1989. Dieldrin was also detected by the CMP sampling effort during Phase 4 at the RMA boundary. Although the averages were all less than those around the former Basin F, the CMP results showed a relative maximum Dieldrin level at AQ3, which is the CMP boundary site most directly downwind from the former Basin F.

Dieldrin was the one target analyte which had detections above the LCRL for both the SVOC and OCP analytical methods. It is not completely valid to compare the averages of the results shown in Tables 4.7-2 and 4.7-3, because of the method for including values below the LCRL. All SVOC Dieldrin results were obtained during the summer of 1990. A graphical comparison of analytical results from SVOC and OCP methods on concurrent samples of Dieldrin is provided in Figure 4.7-5. This figure is a graphical presentation of comparative results from the same sites for the same sampling period; each pair of sample results is indicated by a dot on the figure. The comparison shows a remarkable consistency between the two analytical methods, with a slight tendency for the OCP sample results to be higher than the SVOC results.



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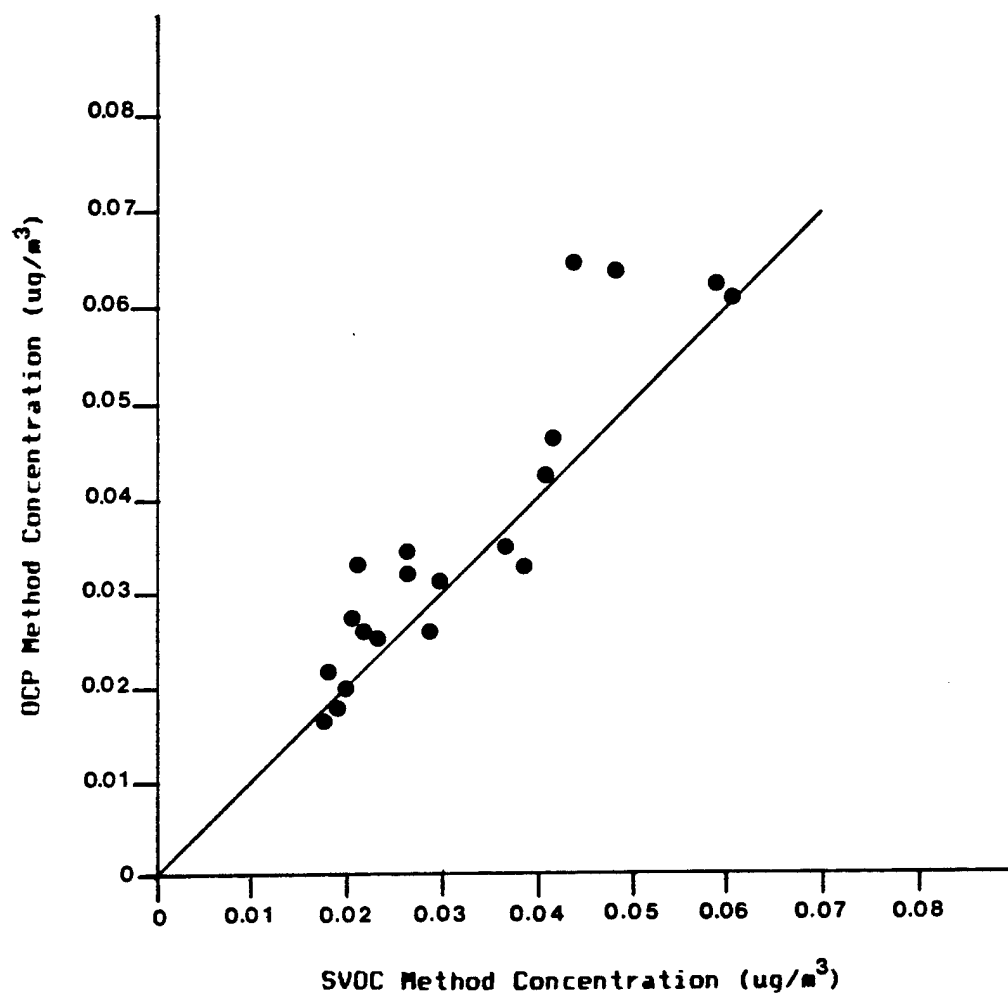
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Figure 4.7-4

Mean and Maximum Concentrations for
Dieldrin by Site, by Phase

Not an Analyte This Phase



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Figure 4.7-5

Comparison of Dieldrin Concentrations from
Identical Samples for Analysis by SVOC and OCP
Methods

These results indicate that Basin F was a source of Dieldrin during the remedial activities. The former Basin F continued to be a source during the later phases, as it was for Aldrin. During Phase 1, Aldrin concentrations were roughly twice those of Dieldrin. By Phases 3 and 4, however, the Dieldrin levels were roughly five to ten times greater than those of Aldrin. These results indicate a relative shift in the pattern of emissions from Basin F following closure. The reasons for this shift in emissions cannot be ascertained from the results reported here. Based on the observed concentrations and on the sample recovery problem for Aldrin, Dieldrin serves as a better indicator compound of emissions from the former Basin F during the later phases.

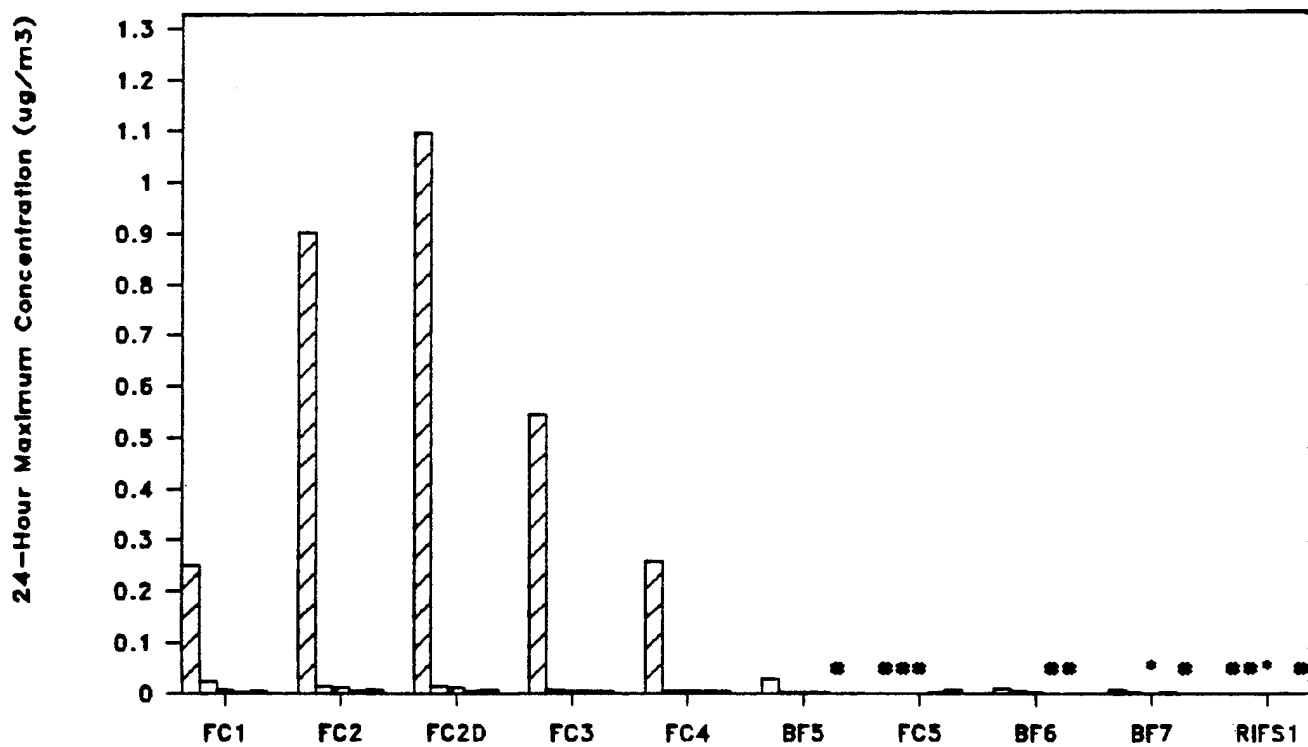
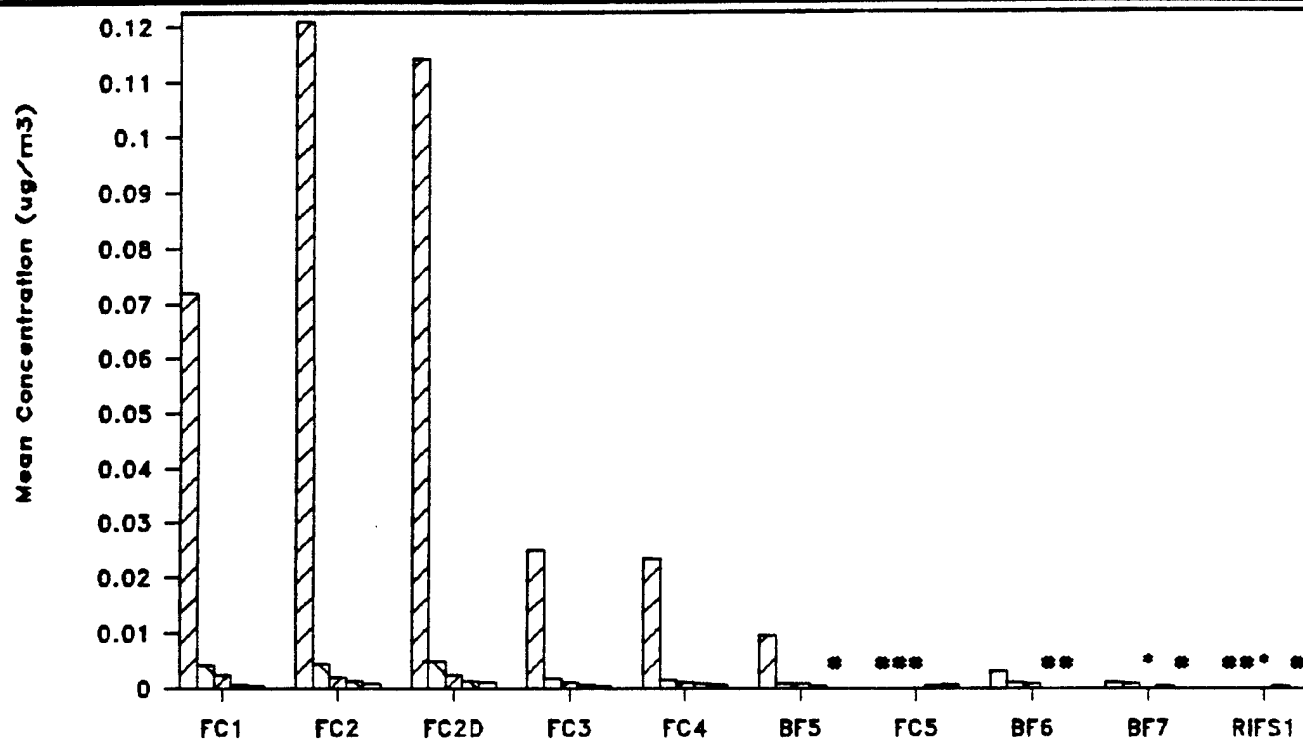
4.7.4.3 Endrin

Endrin was detected in two out of the five sampling episodes around Basin F during the RI program. Concentrations at this time ranged from 0.031 $\mu\text{g}/\text{m}^3$ to 0.13 $\mu\text{g}/\text{m}^3$. Mean and extreme Endrin concentrations for the subsequent sampling programs are shown in Figure 4.7-6 for each site and phase. Again, Endrin levels were greatest during Phase 1 and were relatively higher at the downwind sites than at other sites during all phases. During Phase 4, the CMP reported low but detectable Endrin levels only at boundary site AQ3, downwind from the former Basin F.

The results show that Basin F acted as a source of Endrin during Phase 1, and continued to act as a much weaker source during later phases. Endrin levels were roughly half those of Dieldrin during Phase 1, but were almost an order of magnitude less than Dieldrin levels during Phase 4.

4.7.4.4 Isodrin

Isodrin was detected during the RI program at one site, during one sampling episode, at a level of 0.038 $\mu\text{g}/\text{m}^3$. The summary of Isodrin results for the sampling efforts around Basin F is provided in Figure 4.7-7. Isodrin levels were clearly highest during Phase 1, with the maximum concentrations reported at BF-2 and BF-2C. During Phase 2, Stage 2, there were almost no detections of Isodrin; however, the IRA-F program reported detections in about 9 percent of the total number of samples, mainly at sites directly downwind from former Basin F. Since most Phase 3 and 4 levels were at or near the LCRL, there was no distinct spatial pattern of Isodrin



P1
 P2-S1
 P2-S2
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 P4

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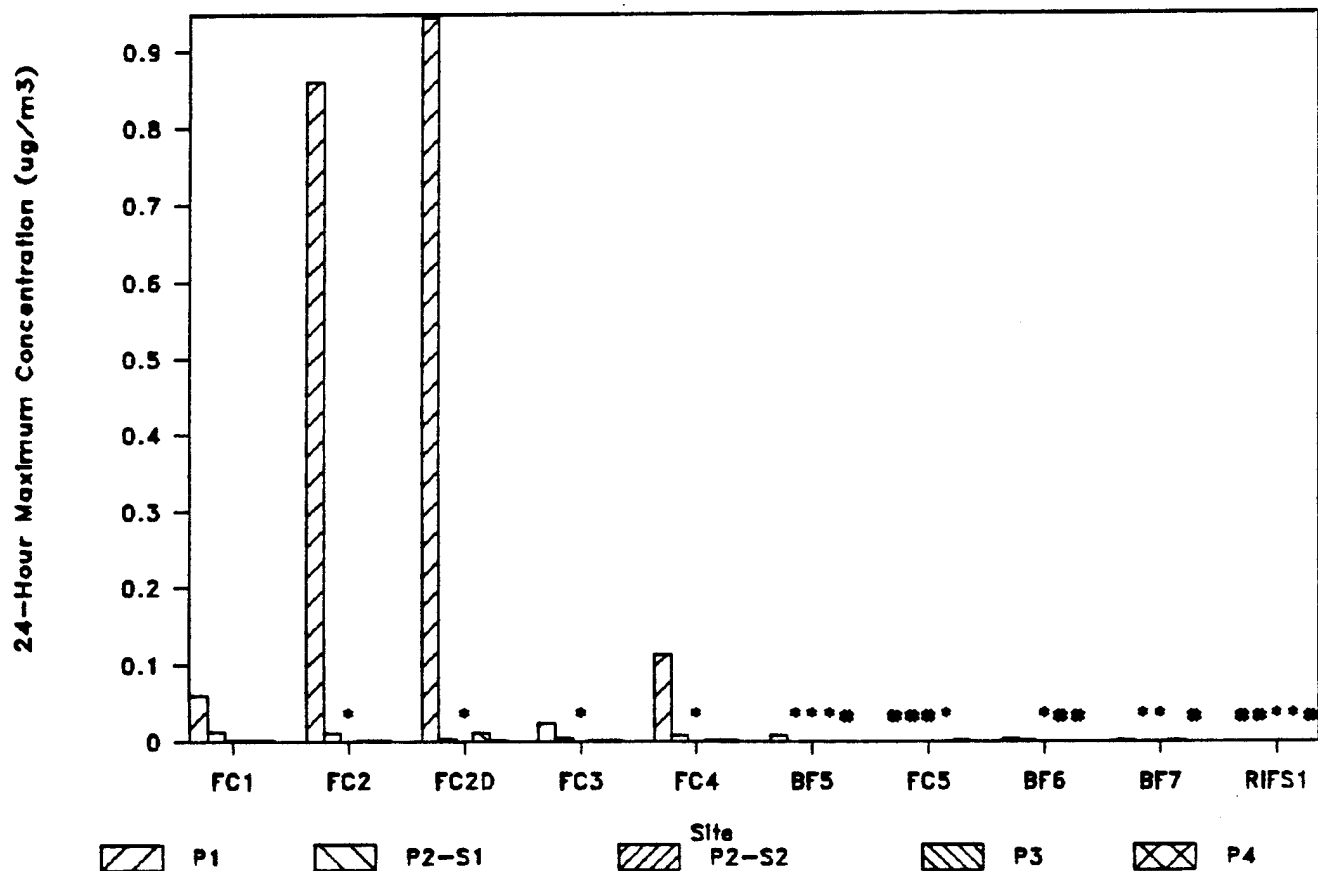
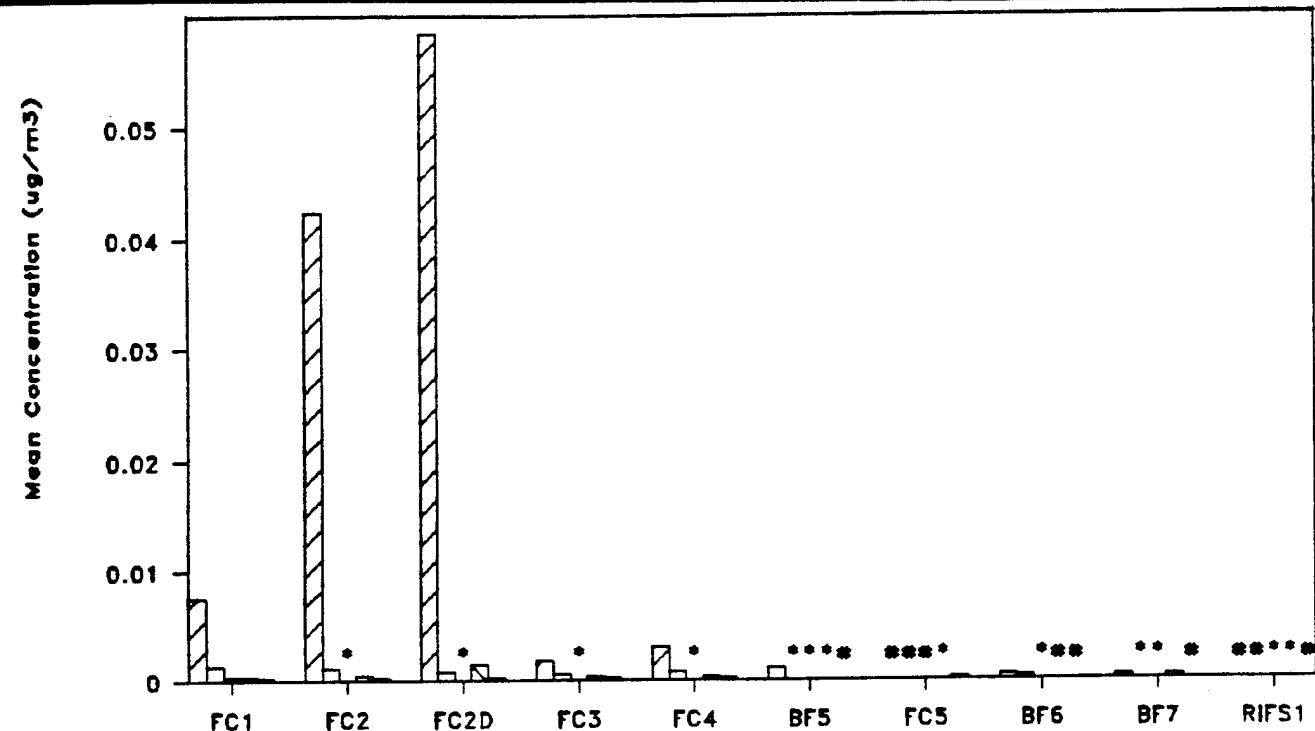
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Figure 4.7-6

Mean and Maximum Concentrations for
Endrin by Site, by Phase

* Not Detected

Not an Analyte This Phase



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Figure 4.7-7

Mean and Maximum Concentrations for
Isodrin by Site, by Phase

* Not Detected

Not an Analyte This Phase

concentrations. Based on the comparative results of Dieldrin, Endrin, and Aldrin, it appeared that the former Basin F continued to be a source of Isodrin during the later phases.

4.7.4.5 Chlorophenylmethyl Sulfone

During the RI, chlorophenylmethyl sulfone (CPMSO₂) was detected during three episodes, with concentrations ranging from 0.024 to 1.7 µg/m³. Chlorophenyl methyl sulfoxide (CPMSO) was detected at two episodes during the RI program. Neither compound was on the target list for the Basin F remedial action monitoring during Phases 1 and 2. The compound CPMSO was not detected in any of the phases reported here; however, CPMSO₂ was detected during the summer months of 1990 (Phase 4) at two IRA-F sites. There were a total of seven detections above the LCRL extending from late May 1990 to early September 1990, all at FC-1 or FC-5. Maximum levels have reached 0.084 µg/m³. These detections included the period prior to May 29 and following July 22. Between those dates there were no SVOC samples taken because the laboratory analytical method was temporarily decertified.

The results indicated that a source of CPMSO₂ had apparently developed near the north area of the former Basin F or at Pond A. As with other SVOCs, the source strength may be seasonally dependent, with maximum emissions occurring during the summer months.

4.7.4.6 Other Compounds

A review of Tables 4.7-2 through 4.7-5 shows that there were minimal detections of other target analytes. Chlordane was detected throughout the IRA-F program (Phases 3 and 4), but was essentially not detected during the preceding phases. This situation is very unusual, because there were no emissions during remedial activities, but there were consistent detections following completion. The IRA-F program reported Chlordane detections in about 30 percent of the total number of samples, with detections at all sites during both phases. During Phase 4, average Chlordane levels were approximately two or three times those of Isodrin. The CMP reported detections of Chlordane, during Phase 4, at the boundary sites. Highest average (0.0005 µg/m³) and 24-hour maximum (0.0029 µg/m³) levels were reported at AQ3, which is downwind from the

former Basin F. The results indicate that Basin F was not a source of Chlordane during remediation, but emissions apparently developed later. This speculation cannot be confirmed with the ambient data reported here.

The analyte ppDDE has only been sporadically detected during the four phases, while ppDDT detections have increased during Phase 4. Similar to Chlordane, the sampled levels were relatively low, but the increase in the number of detections in Phase 4 for IRA-F is somewhat puzzling. This analyte could also be a by-product of the breakdown of stored liquids or wastes.

Other target analytes for SVOCs, including Atrazine, Malathion, Parathion, and Supona were on the target list from the RI period through Phase 4, but there were no detections above the LCRL. The former Basin F has obviously not acted as a measurable source of these compounds.

4.7.5 Nontarget Semivolatile Organic Compounds

Selected SVOC samples were analyzed for nontarget compounds. Each nontarget compound detected was assigned to a group of similar compounds. Statistics were completed for each of these groups of compounds. Tables 4.7-6 through 4.7-14 summarize the results of the nontarget SVOC analyses, by phase, for all sites taken collectively. In Phase 3, samples from all sites for 1 day per month were analyzed for nontargets; in Phase 4, only samples from FC-2 from 1 day per month, were analyzed for nontargets.

In Phases 1 and 2, there were large numbers of detections of acids, isocyanates, cyclohexene, naphthalene, phenols, and phthalates. Other notable compounds detected include aliphatic hydrocarbons, esters, ketones, and polynuclear aromatics (PNA). The more abundant compounds from Phase 3 were aliphatic hydrocarbons, acids, isocyanates, ketones, and phthalates, while Phase 4 yielded significant detection of alkanes, esters, oxygenated hydrocarbons, and phthalates. It is evident that phthalates were present throughout all phases; however their mean concentrations dropped significantly from Phase 1 to Phase 3. Interestingly, these levels increased in Phase 4. Ketones and isocyanates were also present through all four phases. The

mean ketone concentrations increased from Phase 2 to Phase 3, due in large part to a singular maximum value of 0.290 $\mu\text{g}/\text{m}^3$, but then decreased in Phase 4. Isocyanates decreased from Phase 1 to Phase 3 but increased again in Phase 4. Phenols, polynuclear aromatics and naphthalene showed significant reductions from Phase 2 to Phase 3. Naphthalene registered no detections in Phase 4 confirming the results of the VOC nontarget analyses.

From these results it appears that there is no consistent pattern in nontarget compounds. Basin F was a source of compounds such as naphthalene and polynuclear aromatics (PNAs) in Phase 1, but not during Phases 3 and 4. The Basin F area was a likely source of phthalates, ketones, isocyanates and various hydrocarbons during later phases.

Table 4.7-6 Summary of Phase 1 Nontarget SVOC Detections ($\mu\text{g}/\text{m}^3$)

Compound	No. of Detections	24-Hour Maximum	Mean
Acids	8	0.065	0.032
Aldrin	1	0.032	0.032
Alkanes	68	0.109	0.032
Alkenes	3	0.032	0.032
Benzenes	1	0.019	0.019
Chlorophenylmethylsulfide	1	0.026	0.026
Cyclohexenes	10	0.647	0.190
Esters	3	0.029	0.020
Fatty acids	21	7.250	0.610
Isocyanates	4	0.032	0.024
Ketones	3	0.063	0.043
Naphthalenes	1	0.019	0.019
Nitrogen containing compounds	2	0.017	0.017
Phenols	7	0.036	0.027
Phthalates	57	3.260	0.214
Silanes	10	0.031	0.022
Substituted compounds	11	0.035	0.024
Unknown hydrocarbons	14	1.880	0.163
Unknowns	12	6.680	0.585

Table 4.7-7 Summary of Phase 2 Nontarget SVOC Detections ($\mu\text{g}/\text{m}^3$)

Compound	No. of Detections	24-Hour Maximum	Mean
Acids	18	0.035	0.027
Aldehydes	5	0.025	0.022
Alkanes	335	0.270	0.045
Alkanols	1	0.016	0.016
Alkenes	9	0.023	0.019
Amides	1	0.023	0.023
Aromatics	4	0.032	0.022
Benzenes	4	0.027	0.024
Cyclohexenes	46	1.080	0.322
Esters	47	0.305	0.066
Fatty acids	147	2.000	0.049
Furans	10	0.089	0.036
Isocyanates	21	0.069	0.032
Ketones	11	0.059	0.030
Naphthalenes	92	0.096	0.029
Nitrogen containing compounds	2	0.096	0.058
Oxygen containing compounds	27	0.157	0.042
Phenols	81	0.170	0.048
Phthalates	59	2.900	0.182
Poly nuclear aromatics	17	0.032	0.023
Silanes	43	0.203	0.029
Substituted compounds	25	0.092	0.037
Thiophenes	2	0.030	0.028
Toluene	12	1.020	0.154
Trichloromethane	10	0.033	0.023
Trichloropropene	1	0.018	0.018
Unknown hydrocarbons	35	0.203	0.035
Unknowns	38	0.296	0.063

Table 4.7-8 Summary of Phase 3 Nontarget SVOC Detections ($\mu\text{g}/\text{m}^3$)

Compound	No. of Detections	24-Hour Maximum	Mean
Acids	3	0.026	0.023
Aliphatic hydrocarbons	10	0.065	0.027
Cyclohexanes	2	0.024	0.022
Fatty acids	13	0.038	0.026
Isocyanates	11	0.033	0.026
Ketones	25	0.290	0.041
Oxygenated hydrocarbons	2	0.036	0.032
Phenols	1	0.022	0.022
Phthalates	19	0.036	0.024
Silane compound	1	0.020	0.020
Substituted compounds	5	0.038	0.032
Unknowns	1	0.029	0.029

Table 4.7-9 Summary of Phase 4 Nontarget SVOC Detections ($\mu\text{g}/\text{m}^3$)

Compound	No. of Detections	24-Hour Maximum	Mean
2-fluoro-1,1-biphenyl	1	0.139	0.139
Acids	3	0.298	0.117
Aliphatic hydrocarbons	0	0.000	0.000
Alkanes	11	0.036	0.027
Chloro-cyclohexanol	1	0.030	0.030
Cyclohexanes	3	0.024	0.020
Ester	3	0.714	0.254
Ether	7	0.024	0.020
Isocyanates	4	0.091	0.043
Ketones	4	0.030	0.024
Oxygenated hydrocarbons	6	0.089	0.034
Phenols	3	0.104	0.051
Phthalates	19	0.714	0.095
Poly nuclear aromatics	1	0.021	0.021
Silane compound	2	0.119	0.069
Substituted compounds	2	0.059	0.038
Thiophenes	2	0.059	0.042
Unknowns	5	0.174	0.062

Table 4.7-10 Summary of Phase 1 Coeluting Nontarget SVOC Detections ($\mu\text{g}/\text{m}^3$)

Compound	No. of Detections	24-Hour Maximum	Mean
Mirex + unknown alkane	1	0.072	0.072
Phthalate ester + fatty acid ester	1	0.065	0.065
Tetrachlorobenzene + alkane	1	0.021	0.021

Table 4.7-11 Summary of Phase 2 Coeluting Nontarget SVOC Detections ($\mu\text{g}/\text{m}^3$)

Compound	No. of Detections	24-Hour Maximum	Mean
Alkane + naphthalene	7	0.063	0.033
Alkane + unknown	26	0.092	0.034
Benzoic acid + fatty acid ester	2	0.033	0.028
Benzoic acid + substituted benzene	2	0.031	0.030
Benzoic acid + unknown	4	0.033	0.029
C2 naphthalene + acenaphthylene	1	0.032	0.032
C2 phenanthrene + unknown alkane	1	0.025	0.025
Diisocyanato toluene + aromatic fatty acid ester	1	0.019	0.019
Diisocyanato toluene + unknown	2	0.026	0.022
Dimethyl phenol + unknown silane	2	0.023	0.021
Ester + unknown	3	0.032	0.030
Fatty acid ester + aromatic compound	1	0.022	0.022
Fatty acid ester + fluoranthene	6	0.063	0.030
Fatty acid ester + naphthalene	2	0.032	0.032
Fatty acid ester + phenol	4	0.027	0.022
Fatty acid ester + subst. Benzene	1	0.029	0.029
Fatty acid ester + unknown	9	0.034	0.027
Fatty acid ester + unknown alkane	2	0.019	0.019
Methyl naphthalene + unknown silane	5	0.063	0.032
Naphthalene + benzoic acid	1	0.019	0.019
Naphthalene + substituted compound	2	0.021	0.020
Naphthalene + unknown	18	0.094	0.035
Phenol + unknown	5	0.033	0.025
Poly nuclear aromatic + unknown	4	0.035	0.024
Possible dibenzothiophene + unknown	1	0.019	0.019
Substituted benzaldehyde + substituted naphthalene	2	0.051	0.038
Substituted benzaldehyde + unknown	1	0.023	0.023
Substituted benzene + unknown	1	0.016	0.016
Substituted biphenyl + unknown	2	0.019	0.018
Sub. (Phenanthrene or anthracene) + unknown alkane	1	0.031	0.031
Unknown aliphatic + unknown	3	0.032	0.028
Unknown alkane + aryl ether	1	0.019	0.019
Unknown alkane + silane	1	0.033	0.033
Unknown alkane + unknown aromatic	1	0.063	0.063
Unknown alkane + unknown silane	3	0.031	0.029
Unknown coeluting compounds	1	0.019	0.019
Unknown cyclohexanone + unknown	1	0.019	0.019
Unknown silane + phthalate ester	1	0.026	0.026
Unknown silane + unknown	5	0.027	0.022

4.7.6 Annual Cycle of Organochlorine Pesticides Concentrations

As with the VOCs, it is likely that the OCP emissions responded to the annual cycle of climatic conditions at RMA. The seasonal changes in temperatures, as well as less distinct changes in wind patterns and precipitation, are likely to lead to a cycle in the OCP concentrations.

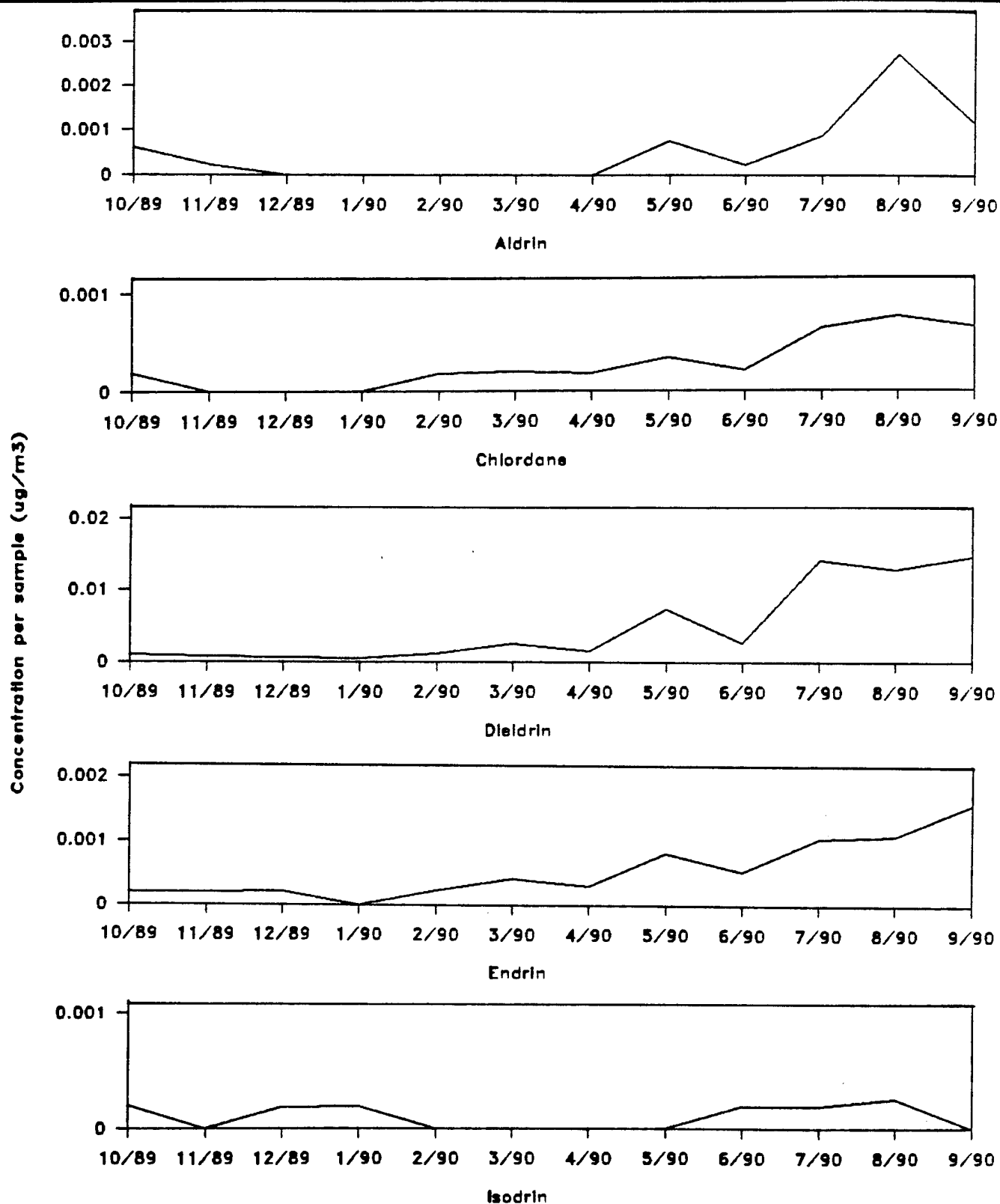
During Phase 4, all remedial activity had ceased, and the annual cycle could be deduced from the mean concentrations at all sites for that period. Figure 4.7-8 shows mean monthly concentrations of selected OCPs for the IRA-F sites for each sample collected during that month. The target analytes that had few detections are not summarized here.

Aldrin concentrations were below the LCRL for the months of December through March and showed a clear maximum monthly level of $0.0027 \mu\text{g}/\text{m}^3$ in August. The Chlordane cycle is similar but with much less amplitude. Dieldrin was detected in all months, with lowest average values in January ($0.0047 \mu\text{g}/\text{m}^3$) and a broad peak of higher values in July, August, and September (0.013 to $0.015 \mu\text{g}/\text{m}^3$). Endrin concentrations showed a similar pattern, with highest values in September ($0.0016 \mu\text{g}/\text{m}^3$). The cycle of Isodrin concentrations is less distinct, with most values below the LCRL. Nevertheless, there is a slight indication of maximum levels during the late summer.

The annual cycle for the target OCPs clearly shows a relative maximum concentration during the late summer and a minimum in mid-winter. This feature indicates that the OCPs emissions were governed by the annual cycle in climate, in particular, the ground temperature or the temperature of the stored liquids or wastes. The strong inversion conditions during winter did not apparently contribute to higher OCP concentrations during those months simply because there were probably much lower emissions at that time.

4.8 CAP AND VENT MONITORING

The potential emissions from the restored Basin F floor, the waste pile cap and the vents on the waste pile, storage tanks, and Pond A were sampled under the IRA-F program. The monitoring



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Figure 4.7-8

Mean Monthly OCP Concentrations for
Phase 4 (FY90)

Note: Different Scales

program consisted of several components, including sampling with real-time sensors for organic compounds (OVA and HNu), for ammonia and hydrogen sulfide. This monitoring also included specialized sampling for target analytes using stainless steel evacuated canisters and using flux chambers. The results of each of these separate components are described below.

4.8.1 Real-time Cap Monitoring

The real-time cap monitoring consisted of traversing both the former Basin F floor and waste pile caps using the integrated real-time organic vapor analyzers. The monitoring technician crossed these surfaces carrying both analyzers and drawing samples from approximately one to two inches above the ground. The sampling locations were set up at the start of the program and included separate sampling grids for the waste pile cap and the former Basin F floor. These sampling locations are shown in Figures 3.3-3 and 3.3-1, respectively. The former Basin F floor sampling locations consisted of 115 marked sites that were approximately evenly spaced across the floor. The waste pile cap sampling locations consisted of 126 marked sites, also spaced fairly evenly over the waste pile cap. These sites were generally located between the waste pile vents.

Sampling was conducted monthly from June through September 1989 and quarterly thereafter, except that the September 1989 event served as the fall 1989 event for the former Basin F floor. In all cases wind speeds were light (generally below 5 mph), and in all but one case the atmospheric pressure dropped during the sampling period. During the August 10, 1989 event on the restored Basin F floor, atmospheric pressure showed an increase of 0.01 inch of mercury over the 3-hour sampling period. Copies of the field data forms for each episode are provided in Appendix C. These forms show the monitoring periods, the meteorological conditions, the real-time readings at each location, along with the field notes.

For every episode all readings at every sampling location on the former Basin F floor and the waste pile cap were below the lower detection limit of 0.1 ppm for both the HNu and OVA sensors. No "hot spots" with elevated emissions were found. During some of the monitoring

episodes, dry surface cracks were noted in the soil, but there were no indications of sunken areas, unusual discoloration, or evident odors. These results indicated that there was no identifiable breach of either the clay cap over the former Basin F floor or over the waste pile cap and liner during the IRA-F monitoring period.

4.8.2 Cap Sampling by Flux Chamber

The former Basin F floor and the waste pile cap were both sampled with flux chambers (flux boxes) during the IRA-F program. Sampling was conducted at six sites, with three on the former Basin F floor and three on the waste pile cap, as shown in Figure 3.3-4. Flux chamber sampling was performed during for three separate episodes on May 10-11, July 25-26, and September 15-16, 1990. Sampling was targeted for both VOCs and SVOCs, using two separate collection techniques and five separate analytical techniques as described in Section 3.4.

In general, the results of the flux chamber sampling effort show that emissions for most of the target compounds were at or below the lower detection limit. Compounds with relatively high or frequent detections at more than one location and during more than one episode are summarized in this section. These results were extracted from the reports submitted by the subcontractor, AeroVironment, who conducted the flux chamber sampling. Summaries of the emissions reported by the subcontractor are presented in Appendix D. For additional detail the reader is referred to these reports (Fitz, 1990a, b, c, and d). Results for each target analyte group (VOCs and SVOCs) by analytical method, are summarized below. The analytical methods employed included gas chromatography in combination with flame ionization detection (GC/FID), electron capture detection (GC/ECD), and mass spectrometry (GC/MS). The details and relative benefits of each of these analytical techniques are discussed in Section 3.6.

4.8.2.1 VOCs by Gas Chromatography/Flame Ionization Detection

A large number of light hydrocarbons were detected with GC/FID, including pentanes, pentenes, butanes, hexanes and hexenes. However, most detections were very low (less than $0.1 \mu\text{g}/(\text{m}^2\text{-min})$) (microgram per square meter per minute), or were comparable to the detection reported

in the field blank. The significant results for the IRA-F target analytes at all sites for the three episodes are shown in Table 4.8-1. Benzene emissions showed relatively high values during the July event but were notably reduced for the other two events. This pattern also holds for toluene at the former Basin F floor sites (FB-4, FB-5, and FB-6). Toluene emissions over the waste pile cap tended to be higher at one site in September than in July. The one outlier ($5.26 \mu\text{g}/(\text{m}^2\text{-min})$), occurred at FB-2 in September, but this value could have been the result of a laboratory error or a very unusual sampling complication. For total xylenes, the highest readings also occurred during the July event.

Other nontarget compounds generally did not show important results because the readings were neither high nor consistent. During the first event, the compound 2-methyl pentane was detected at five sampling locations, and was not detected in the sample field blank. The maximum flux was $0.11 \mu\text{g}/(\text{m}^2\text{-min})$. In the second episode, the maximum increased to $0.22 \mu\text{g}/(\text{m}^2\text{-min})$, and this decreased to three lower detections during the third episode.

The sum of all reported emissions for each analyte is also provided in Table 4.8-1. Except for the one instance in which toluene emissions were unusually high, the July readings tended to be higher than for the other episodes, supporting a contention that emissions were affected by the seasonal ground temperature patterns. At FB-6 on the former Basin F floor, the results showed unusually high emissions for the target analytes and also for the combined total emissions as well during the July event. Either anomalous soil conditions, including vegetation cover, or an unusual mix of materials beneath the soil surface could have been responsible for this situation. This interpretation of these patterns must be used with some caution, however, because the levels reported in the field blanks tended to follow the same patterns among the events.

The laboratory also reported the concentration of total nonmethane hydrocarbons for the last two events. These results are shown in Table 4.8-1. The emission rates were remarkably consistent between the waste pile cap and the Basin F floor, especially for the September event. These results showed that it is not possible to give a broad differential characterization between the

Table 4.8-1 Fluxes of VOCs Analyzed by GC/FID for Each Episode and Each Site

Compound	Episode	Emission Rate ($\mu\text{g}/(\text{m}^2\text{-min})$) by Site							
		Blank	FB-1	FB-2	FB-2c ¹	FB-3	FB-4	FB-5 ²	FB-6
Benzene	May 1990	0.04	0.02	0.02	0.02	0.08	ND ³	ND	ND
	July 1990	0.13	0.04	0.41	0.22	0.33	0.09	0.07	0.34
	Sept 1990	0.01	0.01	0.01	0.01	0.02	0.02	ND	ND
Toluene	May 1990	0.29	0.14	0.38	0.05	0.25	0.03	0.15	0.02
	July 1990	1.17	0.37	0.33	0.22	1.41	0.14	1.00	2.58
	Sept 1990	0.14	0.15	5.26	0.71	0.15	0.06	0.08	0.06
Total Xylenes	May 1990	0.38	0.38	0.04	0.06	0.11	0.12	0.07	0.02
	July 1990	1.13	0.37	0.54	0.27	0.46	0.14	0.07	0.76
	Sept 1990	0.14	0.15	0.52	0.17	0.17	0.07	0.07	0.11
All VOCs	May 1990	1.86	1.10	1.10	0.42	1.05	0.56	0.38	0.38
	July 1990	3.81	2.16	3.74	2.17	4.51	1.24	4.25	7.41
	Sept 1990	1.63	1.65	16.21	2.64	2.23	0.88	1.39	1.20
Nonmethane Hydrocarbons	July 1990	12.9	20.8	26.7	49.0	44.2	13.3	31.9	54.6
	Sept 1990	14.6	26.9	25.3	24.7	32.8	13.6	23.2	26.5

1 Site FB-2c was collocated with FB-2.

2 Site FB-5 reports results from FB-5 and FB-5a, which was relocated for the July 1990 and September 1990 samples.

3 ND = Not detected

waste pile and the former Basin F floor emissions. There were more anomalous patterns within the floor sites and within the waste pile sites than were evident between the two groups.

4.8.2.2 VOCs by Gas Chromatograph/Electron Capture Detection

A total of eight chlorinated VOCs were on the target list for analysis by GC/ECD, including methylene chloride, trichlorofluoromethane, chloroform, 1,1,1-TCE carbon tetrachloride, 1,2-DCE, trichloroethylene, and tetrachloroethylene. Chloroform was detected at relatively low levels, with no consistent pattern, in five out of 21 samples.

Carbon tetrachloride was detected at levels near those recorded by the blank sample during the first event, and was detected at only one site following that event. The analyte 1,2-dichloroethane was detected only once in 21 samples. Because there was a misinterpretation of the analyte list, trichlorofluoromethane was on the target list for the first event only, and methylene chloride was on the target list for the remaining two episodes.

Trichlorofluoromethane emissions were detected at three sites during the first event, and the rates were relatively high compared to other analytes. Emissions ranged from 0.10 $\mu\text{g}/(\text{m}^2\text{-min})$ to 2.72 $\mu\text{g}/(\text{m}^2\text{-min})$ with a field blank value of 0.84 $\mu\text{g}/(\text{m}^2\text{-min})$. With the high field blank value, it is likely that these emission rates do not reflect a consistent pattern.

For the remaining compounds, Table 4.8-2 presents the emissions at each site for each event. The 1,1,1-trichloroethane emissions were above those of other compounds for the first and last events, with emissions at waste pile sites generally higher than those of the former Basin F floor. Curiously, there were no reported emissions during the July 1990 event. This situation may have been the result of an analytical problem, and the other two events should be taken as being more representative of emissions overall. Trichloroethylene and tetrachloroethylene emissions were higher during the May event than during the other events. Tetrachloroethylene emissions were anomalously high at FB-4, on the Basin F floor, during the first episode. Methylene chloride

Table 4.8-2 Fluxes of VOCs Analyzed by GC/ECD for Each Episode and Each Site

Compound	Episode	Emission Rate ($\mu\text{g}/(\text{m}^2\text{-min})$) by Site							
		Blank	FB-1	FB-2	FB-2c ¹	FB-3	FB-4	FB-5 ²	FB-6
1,1,1,-Trichloroethane	May 1990	0.15	0.25	0.39	0.38	0.19	0.12	0.35	ND
	July 1990	ND ³	ND	ND	ND	ND	ND	ND	ND
	Sept 1990	ND	0.55	3.55	0.60	0.31	ND	0.24	0.11
Trichloroethylene	May 1990	0.19	0.26	0.36	0.35	0.07	ND	ND	ND
	July 1990	0.03	ND	0.03	ND	0.03	ND	0.04	0.04
	Sept 1990	ND	ND	0.19	0.03	0.02	ND	0.01	0.01
Tetrachloroethylene	May 1990	ND	0.34	ND	ND	0.14	1.06	0.33	ND
	July 1990	ND	ND	ND	ND	ND	ND	ND	ND
	Sept 1990	ND	0.01	ND	0.01	0.02	ND	ND	0.01
Methylene Chloride	July 1990	ND	ND	1.31	0.16	ND	ND	ND	0.39
	Sept 1990	0.57	6.78	ND	0.36	0.33	0.27	ND	ND

1 Site FB-2c was collocated with FB-2.

2 Site FB-5 reports results from FB-5 and FB-5a, which was relocated for the July 1990 and September 1990 samples.

3 ND = Not detected

emissions were also rather sporadic, with a single extreme value. No consistent pattern of emissions can be determined.

From these results it can generally be surmised that emissions of 1,1,1-trichloroethane were about $0.8 \mu\text{g}/(\text{m}^2\text{-min})$ on the waste pile cap, and that emissions of trichloroethylene are about $0.17 \mu\text{g}/(\text{m}^2\text{-min})$ on the waste pile cap. Data for other analytes show some relative spikes or high readings, but were not sufficiently consistent to draw further conclusions.

4.8.2.3 VOCs by Gas Chromatography/Mass Spectrometry

The VOC analysis by GC/MS provides additional results for target compounds analyzed in GC/FID and GC/ECD, although the lower detection limit is higher than those of the other two methods. This means that the GC/MS method is the least sensitive. Several Freons were detected in the analyses, but field blank values tended to be high, and there was a good deal of variability among the sites. The maximum Freon emission was $6.2 \mu\text{g}/(\text{m}^2\text{-min})$ at FB-2 in September 1990.

For most analytes, detections were generally very small and tended to be sporadic, with little consistency among the levels or the frequency of detection. Analytes with some consistency are summarized in Table 4.8-3. Chloromethane showed relatively high emissions during the July event at all sites, but there were no detections during the subsequent event. Dichloromethane showed relatively high emissions during the first and last event, with no detections in the July event. The analyte 1,1,1-trichloroethane had detections in 10 out of 12 samples on the waste pile, with detections during each event. An extreme maximum of $6.0 \mu\text{g}/(\text{m}^2\text{-min})$ was reported for FB-2 from the September event.

Toluene was also reported for each event and was detected in 11 out of 12 samples on the waste pile. Average waste pile emissions were just above $1.0 \mu\text{g}/(\text{m}^2\text{-min})$ for all sites and events. Toluene was the only analyte to be consistently reported by both the GC/FID and GC/MS analytical methods. The emission rates were somewhat comparable. The mean emission rate

Table 4.8-3 Fluxes of VOC Compounds Analyzed by GC/MS for Each Episode and Each Site

Compound	Episode	Emission Rate ($\mu\text{g}/(\text{m}^2\text{-min})$) by Site							
		Blank	FB-1	FB-2	FB-2c ¹	FB-3	FB-4	FB-5 ²	FB-6
Chloromethane	May 1990	0.20	ND	0.18	ND	0.16	ND	ND	ND
	July 1990	ND ³	3.81	0.20	0.68	2.01	0.83	0.32	2.14
	Sept 1990	ND	ND	ND	ND	ND	ND	ND	ND
Dichloromethane	May 1990	0.62	0.17	0.56	ND	0.81	0.54	0.77	0.45
	July 1990	ND	ND	ND	ND	ND	ND	ND	ND
	Sept 1990	0.58	1.01	0.72	0.85	1.01	0.89	0.76	0.71
1,1,1-Trichloroethane	May 1990	0.27	0.58	0.44	0.13	0.23	ND	0.25	ND
	July 1990	0.16	0.19	ND	0.17	0.26	ND	0.44	0.48
	Sept 1990	ND	ND	6.00	0.41	0.34	ND	ND	ND
Toluene	May 1990	0.22	0.17	0.29	ND	0.16	ND	0.12	ND
	July 1990	0.19	0.27	0.46	0.29	2.09	0.17	6.42	3.45
	Sept 1990	0.10	0.19	7.82	0.91	0.15	ND	ND	ND
4 - Ethyltoluene	May 1990	ND	ND	0.28	0.14	0.13	ND	ND	ND
	July 1990	ND	0.21	0.19	0.17	0.16	ND	ND	0.25
	Sept 1990	ND	ND	0.42	ND	ND	ND	ND	ND
1,2,4-Trimethylbenzene	May 1990	0.12	0.42	0.21	0.17	0.19	ND	ND	ND
	July 1990	ND	0.16	0.17	0.15	0.14	ND	0.13	0.21
	Sept 1990	ND	ND	0.44	ND	ND	ND	ND	ND
m - Dichlorobenzene	May 1990	ND	0.34	0.23	0.20	0.26	ND	ND	ND
	July 1990	ND	ND	ND	ND	ND	ND	ND	ND
	Sept 1990	ND	ND	ND	ND	ND	ND	ND	ND

1 Site FB-2c was collocated with FB-2.

2 Site FB-5 reports results from FB-5 and FB-5a, which was relocated for the July 1990 and September 1990 samples.

3 ND = Not detected

detected by the GC/FID method for the waste pile sites was approximately $0.75 \mu\text{g}/(\text{m}^2\text{-min})$ for all sites and events. In addition, the relative maximum at FB-2 for the September event was consistent between the two analyses (5.26 and $7.82 \mu\text{g}/(\text{m}^2\text{-min})$), and the high readings at the former Basin F floor sites during the July event were also consistent with one another. Toluene appeared to be the most consistently observed analyte emitted from both areas, with higher readings on the waste pile, and a distinct seasonal (ground-temperature related) cycle on the former Basin F floor.

Two other compounds, 4-ethyl toluene and 1,2,4-trimethyl benzene, showed relatively consistent emissions from the waste pile, as shown in Table 4.8-3. These compounds were detected at several waste pile sites for the first episode, but were detected only at FB-2 during the final episode. M-dichlorobenzene was detected at all waste pile sites during the first event, but was not detected at any site during the subsequent events.

It is important to note the analytes that were **not** detected at any of the waste pile or the former Basin F floor sites for this analysis. These compounds included 1,1-dichloroethane, chloroform, 12DCLE, benzene (which was detected by GC/FID), carbon tetrachloride, hexachlorobutadiene, dibromochloropropane, acetone, dimethyl disulfide, methyl isobutyl ketone, trans-1,2-dichloroethylene, DCPD, and BCHPD. Other target analytes showed infrequent or irregular emission rates.

4.8.2.4 SVOCs by Gas Chromatograph/Electron Capture Detection

Analysis of SVOCs by GC/ECD provided a sensitive analysis for OCPs. A synopsis of emission rates for selected target analytes is provided in Table 4.8-4. These results are from the data provided for each event which is supplied in total in Appendix D. Analytes with consistent or relatively high emission rates are presented here. For these compounds the lower detection limit (LDL) is $0.0005 \mu\text{g}/(\text{m}^2\text{-min})$.

Table 4.8-4 Surface Fluxes of SVOCs Detected by GC/ECD for Each Sampling Site and Episode

Compound	Episode	Emission Rate ($\mu\text{g}/(\text{m}^2\text{-min})$) by Site							
		Blank	FB-1	FB-2	FB-2c ¹	FB-3	FB-4	FB-5 ²	FB-6
Heptachlor	May 1990	ND ³	ND	ND	ND	ND	ND	ND	ND
	July 1990	0.013	0.004	0.005	0.001	0.011	0.036	0.005	0.018
	Sept 1990	ND	0.004	ND	ND	0.020	0.006	ND	0.002
Endrin	May 1990	ND	ND	ND	ND	ND	0.003	0.005	0.004
	July 1990	ND	ND	ND	ND	0.008	0.023	0.013	ND
	Sept 1990	ND	ND	ND	ND	ND	ND	ND	ND
Aldrin	May 1990	ND	ND	ND	ND	ND	ND	ND	ND
	July 1990	ND	ND	ND	ND	ND	0.005	ND	ND
	Sept 1990	ND	0.002	ND	ND	0.004	ND	ND	0.005
Endosulfan I	May 1990	ND	ND	ND	ND	0.004	ND	ND	ND
	July 1990	ND	ND	ND	ND	ND	ND	ND	ND
	Sept 1990	ND	0.003	ND	0.003	0.005	0.002	0.008	0.038

1 Site FB-2c was collocated with FB-2.

2 Site FB-5 reports results from FB-5 and FB-5a, which was relocated for the July 1990 and September 1990 samples.

3 ND = Not detected

Heptachlor was not detected at any site during the first event, but was detected at all sites during the second event, and at four sites during the final event. A relatively high field blank value for this compound was noted from the July event. The maximum emission rate for heptachlor was $0.036 \mu\text{g}/(\text{m}^2\text{-min})$ during the July event.

Endrin was detected at three sites on the former Basin F floor during the May episode. It was also detected during the second event at three sites, two of which were on the Basin F floor, with a maximum emission of $0.023 \mu\text{g}/(\text{m}^2\text{-min})$. Endrin was not detected in the September episode. Aldrin was not detected in the May episode, but was detected at one site in July, and at three sites in September. Endosulfan I was detected at one site in May, at no sites in July and at all sites in September.

There was only one detection of Dieldrin emissions among all 21 samples, and there were four detections of ppDDE, two detections of ppDDT, and no detections of Chlordane. No clear emission patterns for SVOCs emerged from these results.

4.8.2.5 SVOCs by Gas Chromatograph/Mass Spectrometry

The GC/MS analytical technique for SVOCs includes a larger number of target compounds, but the LDL was approximately 100 times greater than that of the GC/ECD method ($0.05 \mu\text{g}/(\text{m}^2\text{-min})$). Analytes included hexachlorobutadiene, naphthalene, hexachlorocyclopentadiene, Atrazine, CPMSO, CPMSO₂, Malathion, Parathion, and Supona. For all three events at all six sites, there were no detections of emissions of SVOCs above the detection limit for this method.

4.8.3 Real-Time Vent Monitoring

The waste pile and Pond A vents and the tanks were monitored nine separate times during the IRA-F program. Monitoring was conducted monthly from June through September 1989 and quarterly thereafter. Readings were taken with both the HNu and OVA sensors and with ammonia and hydrogen sulfide detection tubes during each event. The results of each of these

monitoring efforts are described below. Copies of the field data sheets, indicating the readings taken at each vent for each episode, are provided in Appendix C.

4.8.3.1 Waste Pile Vents

The waste pile vents were installed to relieve potential buildup of pressure resulting from the vaporization of contaminants in the waste pile. In all, there are 25 vents on the waste pile, placed in a five-by-five grid and spaced an average of 100 feet apart. A depiction of the location of these vents, including the assigned vent numbers, is provided in Figure 3.3-1. The waste pile vents are approximately 6 inches in diameter and extend from below the upper waste pile liner, through the waste pile cap into the atmosphere. At the top the vents are curved to open downward. Flow is completely passive, with no devices to enhance or restrict flow. A schematic depiction of a typical waste pile vent is provided in Figure 3.3-2.

As noted in Section 3, the vents were sampled on days with light winds and with falling atmospheric pressure. Sampling was conducted by drawing a sample from approximately 1 inch below the lip of the vent opening on the downwind side. Readings were taken in this fashion to characterize potential emissions into the atmosphere. Although actual emission rates may be difficult to estimate with this method, the relative emission pattern among the vents and any changes with time should be adequately characterized.

Table 4.8-5 provides a summary of the waste pile vent readings. Included are the sample date, the average of the OVA readings for all 25 vents, and the recorded maximum reading and the vent number that had the maximum reading for each sampling date. Maximum readings were clearly noted in August 1989 and again during the summer of 1990. Vents 5, 9, 16, and 20 produced the highest readings. These four vents are located randomly across the waste pile cap, indicating that there was no one portion of the waste pile that produced elevated emissions. Readings with the HNu were consistently less than those of the OVA, but tended to show similar patterns.

Table 4.8-5 **Summary of OVA Readings (ppm) at the Waste Pile Vents**

Sample Date	Average	Maximum	Location of Maximum	Frequency of Occurrence of Concentration Ranges (ppm)			
				0.0	0.1-1.0	1.1-10	>10
June 1, 1989	0.4	2.8	20	8	15	2	0
July 19, 1989	0.3	2.4	5	17	5	3	0
Aug 24, 1989	2.2	28.0	20	1	16	7	1
Sept 27, 1989 ¹	0.5	4.2	20	10	11	3	0
Dec 4, 1989	1.0	3.2	16	1	15	9	0
Feb 7, 1990	3.0	10.3	9	0	7	17	1
May 22, 1990	5.0	44.0	5	0	7	16	2
July 16, 1990	2.5	14.0	16	6	7	11	1
Aug 15, 1990	6.8	36.0	9	3	4	12	6

¹ Vent # 4 was not sampled on September 27, 1989 because the exhaust of a nearby generator interfered with readings.

Also shown on Table 4.8-5 are the number of vents with readings within specified ranges (0.0; 0.1 to 1.0; 1.1 to 10; above 10 ppm). The number of vents in each category changed during the course of the IRA-F program. Specifically, most vents had relatively low readings during the first months of the program; however, during the latter part of the program, there were consistently more readings above 1.0 ppm. During the final event there were 6 readings above 10 ppm. These data show a trend for increasing emissions at all vents across the waste pile. There was also a clear seasonal peak, with highest readings during the summer, but the long-term trend for increasing emissions is clear.

Hydrogen sulfide and ammonia readings were taken during most events, but there were no detections of these compounds above the detection limit of 0.1 ppm at any vent at any site during the program.

4.8.3.2 Real-Time Pond A Readings

Pond A, a rectangular, double-lined pond (liners on the top and the bottom) contains liquid wastes from former Basin F. Four vapor release vents were installed at the edges of Pond A, one at the center of each edge. Each vent was fitted with a trip valve that allowed vapors to be emitted but prevented air from being drawn into Pond A and under the upper liner. Consequently, emissions from the pond came in short pulses as the valve was tripped to emit gases. A total of eight separate monitoring episodes were conducted during IRA-F. The fall 1989 event was conducted near the end of September, and there were two separate events during February 1990, one when Pond A was covered with snow and ice, and the other when only a thin layer of ice covered parts of the upper liner.

A summary of the Pond A OVA readings is provided in Table 4.8-6, including the readings at each vent for each episode, along with the average and maximum readings for each event. The readings represent maximum values noted on the OVA as a pulse was emitted and the OVA responded. Generally, the vent which was downwind from Pond A during the sampling episode

recorded the highest readings. There was an evident tendency for the south vent to have the highest readings when the wind was from the east-southeast and north-northeast, however.

For all but one episode, the maximum vent reading was above 100 ppm and reached as high as 540 ppm. The lowest vent reading for each episode was generally in the range of 0.0 to 2.0 ppm. Apparently the action of the wind caused a shift in the location of vapor bubbles beneath the liner and thus shifted the maximum emissions, with the downwind vent recording the maximum readings. The event during which Pond A was covered with snow and ice (February 7, 1990) showed the lowest maximum reading and the highest minimum reading, indicating that the wind action was not having an effect at that time. The early summer months (June 1989 and May 1990) showed the highest average readings, indicating a likelihood of elevated vaporization just after the coldest months, probably caused by a rapid rise in pond temperature at that time. As the warmer summer months progressed, readings diminished.

4.8.3.3 Real-Time Tank Readings

Each of the three tanks in the tank farm was fitted with a vent on its roof. This vent was only accessible by using an extension tube attached to the probes of the sampling instruments. During the IRA-F program, OVA and HNu readings were taken from each tank vent for each of six events.

The tank locations are shown in Figure 3.3-5. The field data sheets for this effort are presented, along with the Pond A readings, in Appendix C. On the field data sheets, the east tank actually refers to the northeast tank, and the west and south tanks are clearly identifiable. A summary of the OVA readings from the tanks is given in Table 4.8-7. The summary shows that there was effectively no consistent difference in readings among the three tanks. The data also show that there were relatively high readings during the summer months of 1990, with a relative maximum in August 1989. Aside from the seasonal pattern, there was also an evident minor but continual increase in readings during the course of the program.

Table 4.8-6 Summary of OVA Readings (ppm) at Pond A

Sample Day	Vent				Average	Maximum	Wind Direction
	N	W	S	E			
6/2/89	1.6	63.0	400.0	120.0	146	400.0	ESE
7/19/89	0.0	100.0	310.0	1.2	103	310.0	NNE
8/24/89	1.8	70.0	200.0	2.8	69	200.0	NNE
9/27/89	70.0	22.0	420.0	0.0	128	420.0	NNE
2/7/90	59.0	21.0	6.8	35.0	31	57.0	S
2/12/90	310.0	7.7	1.4	0.0	80	310.0	S
5/31/90	1.2	34.0	540.0	510.0	271	540.0	SW
7/16/90	0.0	110.0	66.0	0.3	44	110.0	E

Table 4.8-7 Summary of OVA Readings (ppm) at the Tank Farm

Sample Date	TANK			Average
	W	E	S	
6/5/89	0.2	0.4	0.1	0.23
7/19/89	2.8	2.8	2.4	2.67
8/24/89	6.7	6.6	5.3	6.20
2/12/90	1.6	1.2	3.6	2.13
5/5/90	92.0	7.4	114.0	71.13
7/16/90	42.0	28.0	22.0	30.67

4.8.4 Canister Sampling

Evacuated stainless steel (Summa passivated) canisters were used to draw samples from the vents and from the tank farm to allow the characterization of the constituent vapors in the vents. Emissions from this vent were impossible to characterize because the vent was inaccessible to the field personnel. No safe access method could be provided. However, a sample port provided access to the vapor space above the tank liquid from the top of the tank stairway. The sampling and analysis was conducted in accordance with the guidelines provided in EPA Method TO-14. In all cases, a relatively short period grab sample was taken, and the canisters were shipped to a subcontractor laboratory for analysis. The analytical results for all canister sampling events are presented in Appendix E. Target analytes included an expansion of the IRA-F VOC target list. No SVOCs were analyzed by this method. Three separate sampling efforts were conducted during 1990. The waste pile vents were sampled all at one time as one group, and the Pond A vents and tank farm vapors sampled at another time. A comparison of results for these separate efforts is provided below.

One major advantage of the canister sampling and analytical method is that the canisters samples could be reanalyzed to increase the range of detections for the target compounds. In these instances, the air sample could be diluted to obtain actual concentrations for those compounds with the highest concentrations. For all but the February waste pile event, this dual analysis was conducted.

4.8.4.1 Waste Pile Vent Canister Sampling

Waste pile vents were sampled on February 8, June 18, and August 15, 1990. Vents 5, 20, and 23 were sampled during all episodes, and Vent 9 was sampled during the last two episodes. The locations of these vents are shown in Figure 3.3-1. During the February event, a sample was drawn from approximately one inch below the lip of the vent on the downwind side, similar to real-time sampling with the HNu and OVA sensors. The results for many of the compounds were below the detection limit and, therefore, were somewhat inconclusive. During the latter two episodes, the samples were drawn from approximately 12 to 18 inches inside the throat of the

vent. This approach provided relatively high concentrations of the target analytes, and provided a suitable comparison of their relative concentrations.

A tabular presentation of the results of these three efforts is shown in Table 4.8-8 for all target analytes which were reported above the detection limit. The relatively lower concentrations during the first event were most likely due to the different sampling techniques. The results showed that chloroform was detected at higher levels than was any other target analyte. In February, the maximum chloroform level was 18 ppm, and in June and August the levels reached 100 and 130 ppm, respectively. These elevated levels were noted at Vent 23. At vent 20 the concentrations were almost 100 times less than the Vent 23 concentrations. At the other locations, Vents 5 and 9, the chloroform readings ranged from 3.9 ppb to 6.7 ppb during June and August.

The second and third highest concentrations for the target analytes were for bicycloheptadiene and dicyclopentadiene, with maximum readings reaching roughly 2 ppm. Tetrachloroethylene was consistently detected during June and August, and there was a fairly consistent detection of Freons as well. Vent 23 had both the highest levels of chloroform and the largest number of detections for the target analytes. Chloroform was present in all sampled vents at the highest concentrations, and could well serve as an "indicator compound" for emissions from the waste pile vents.

Emission rates from the waste pile vents were estimated by attaching commercially available polyethylene bags to the vent, noting the time required to fill the bag, and using the bag volume to calculate a flow rate from the vent. Since the vents were passive, other more sophisticated techniques would have interfered with the attempt to measure vent emissions, and might not have provided a sufficient increase in accuracy to warrant their cost. The bag-filling technique provided sufficiently accurate results for estimating emissions.

Table 4.8-8

Concentrations of Detected Target Analytes (ppb) in Canister
Samples for the Basin F Waste Pile Vents

Episode/ Analyte	5	9	Sample Vent 20	23	Collocated Vent
<u>February 8</u>					(20) ¹
Freon 12			45		13
Freon 11	7.7		2.4		
Freon 113	10		7.9		2.3
Chloroform	240		70	18,000	21
Tetrachloroethene	17				
Bicycloheptadiene	14				
Dicyclopentadiene	43				
<u>June 18</u>					(5) ¹
Freon 12			64		
Chloroethane	33			140	31
Freon 11			24		
Freon 113	110	130	64	24	12
Methylene Chloride	13			150	16
1,1-Dichloroethane				35	
Chloroform	6,100	3,900	1,400	100,000	6,600
Carbon Tetrachloride				86	
1,2-Dichloroethane				25	6.8
Trichloroethene	5.5			28	6.1
Toluene				14	
Tetrachloroethene	340	500	40	640	360
1,2,4-Trimethylbenzene	7.1				
Bicycloheptadiene	300	300		1,000	320
Dicyclopentadiene	1,800	1,100	29	1,100	2,200
<u>August 15</u>					(9) ¹
Freon 12			51		
Chloromethane		14		180	24
Freon 11			35		
Freon 113	100	130	74	160	50
Methylene Chloride				26	
1,1-Dichloroethane				35	
Chloroform	5,000	4,100	1,400	130,000	6,700
1,1,1-Trichloroethane			14		
Carbon Tetrachloride				84	
Benzene	7.0			21	
1,2-Dichloroethane				13	
Trichloroethene				30	
Toluene				13	
1,1,2-Trichloroethane				840	
Tetrachloroethene	300	590	67		740
Bicycloheptadiene	230	510		2,000	790
Dicyclopentadiene	1,400	800		800	1,200

1 Collocated vent number, which varies with episode

2 Blank = Not detected

A summary of calculated flow rates in cubic centimeters per second (cc/sec) and chloroform emission rates is provided in Table 4.8-9, along with the concurrent HNu and OVA readings. Results showed that chloroform emissions from Vent 23 were substantially higher than emissions from other vents. Because the ionization potential of chloroform is slightly above the optimum detection range for the OVA and HNu sensors, it is not surprising that the real-time readings and the calculated chloroform emissions were not consistent. An instrument or a detection tube that focuses on chloroform as a target analyte should provide the best indicator for determining emissions from the waste pile vents. Emission rates for other target compounds reported in Table 4.8-8 could be calculated based on their molecular weight and the flow rates shown in Table 4.8-9.

4.8.4.2 Canister Sampling at Pond A

During separate episodes of canister sampling than at the waste pile vents, canister sampling was conducted on the Pond A vents and the tank vapors. At Pond A, the sample was drawn from the vent with the highest OVA readings, and this was usually the downwind vent. Sampling was conducted on April 19, July 18, and August 28, 1990. Samples were drawn from the south vent during the first and last episodes and from the east vent during the July episode.

Results for these three events are summarized in Table 4.8-10. Only the diluted analysis for the July event was valid, and therefore there were no concentrations below about 2,000 ppb reported for that analysis. The most striking result is the range of concentrations for the reported analytes. Freon 12 and Freon 114 were detected in relatively high concentrations. These compounds were not on the IRA-F target list but were reported by the analytical laboratory as a matter of course. These compounds are likely a result of deterioration of the layer of styrofoam that floats on the liquids, keeping the cover liner afloat.

Chloromethane was also detected in very high concentrations at all events, with concentrations reaching 590,000 ppb during the July event. Three other analytes showed relatively high concentrations, including 1,1,1-trichloroethane, trichloroethylene, and tetrachloroethylene, with

Table 4.8-9

**Estimated Flow Rates Emission Rate for Chloroform and
Organic Vapor Readings for Basin F Waste Pile Vents**

SAMPLE DATE	DATA (units)	VENT			
		5	9	20	23
6/18/90	Flow rate (cc/sec)	240	270	186	93
	Emission rate (ug/sec)	7.2	4.8	1.2	42
	OVA Reading (ppm)	14	52	4.2	36
	H-Nu Reading (ppm)	1.8	1.0	0.2	2.4
8/15/90	Flow rate (cc/sec)	370	71	124	202
	Emission rate (ug/sec)	8.4	2.2	0.8	120
	OVA Reading (ppm)	11	36	10	22
	H-Nu Reading (ppm)	1.0	0.4	0	1.8

Note: Emission rate calculation used flow rate estimates provided here, chloroform concentration from Table 4.8-8, and a conversion from standard conditions to on-site estimates.

Table 4.8-10

Concentrations of Target Compounds in the Pond A Vent Emissions
for Three Episodes

Analyte	Concentration (ppb) for Events			
	April - S. Vent	July - E. Vent	August - S. Vent	Average
Freon 12	390,000	370,000	280,000	350,000
Chloromethane	390,000	590,000	540,000	510,000
Freon 114	650,000	1,000,000	730,000	790,000
Chloroethane			120	
Freon 11	76		48	
Freon 113	7.2			
Acetone	80		500	
Methylene chloride	110		180	
1,1 - Dichloroethylene			35	
2 - Butanone	280		380	
Chloroform	81		310	
1,1,1 - Trichloroethane	6,500	2600	9,300	6,100
Carbon Tetrachloride	230		250	
Benzene	18			
Trichloroethylene	20,000	5500	18,000	15,000
Toluene	360		280	
Tetrachloroethylene	7,400	4800	13,000	8,400
Ethyl benzene	480		640	
Total Xylenes			3,100	
4 - Ethyl Toluene	8.7		14	
1,2,4 - Trimethylbenzene	9.0		15	
Dimethyl disulfide	14		410	

Blank = Not detected

average concentrations of 6,100, 15,000, and 8,400 ppb, respectively. Averages for the other analytes, which were not reported for the second event, are not reported.

Acetone, total xylenes, and dimethyl disulfide showed dramatic increases in concentrations from the first to the last event. Lower and somewhat consistent levels were reported for methylene chloride, 2-butanone (methyl isobutyl ketone), chloroform, carbon tetrachloride, toluene, and ethylbenzene. For all these compounds except toluene, there was a tendency for higher concentrations during the August event.

4.8.4.3 Canister Sampling at the Tanks

Canister sampling was conducted at all three tanks during the same three episodes identified for the Pond A canister sampling effort. Samples were drawn from the vapor space above the tank liquid. These results are reported for selected target compounds in Table 4.8-11. The concentrations for each tank and each event are reported, and the average concentration for each compound from each event are also provided.

Similar to the results of the Pond A sampling effort, the data show a wide range of concentrations among the target analytes. Chloromethane had the highest concentrations for all events, and the levels of acetone and dimethyl disulfide were second and third highest among the other analytes. For all three analytes, there was a notable increase in concentration from the first to the last event. Average concentrations ranged from 3,900 ppb to 14,000 ppb for chloromethane, from 1,300 to 4,100 ppb for acetone, and from 250 to 2,500 ppb for dimethyl disulfide. External impacts of emissions from the tanks could clearly be tracked by determining the ambient concentrations of these three analytes.

For most other compounds, the concentrations also increased from the first to the last episode and this pattern appears to hold consistently among the tanks. In general, the reported levels among the three tanks were roughly equivalent to one another. These results lend credibility to the overall sampling and analytical technique.

Table 4.8-11 Concentrations of Detected Target Analytes at the Tank Farm

Target Analyte	Event*	Concentration at Each Tank (ppb)				Average
		W	WC	E	S	
Chloromethane	1	4,000	2,700	6,200	2,800	3,900
	2	2,800	4,900	5,300	5,200	4,600
	3	15,000	15,000	14,000	13,000	14,000
Bromomethane	1	51	42	42	35	43
	2	77	100	52	88	79
	3	110	110	97	83	100
Chloroethane	1	23	20	20	18	20
	2	96	81	77	94	87
	3	98	95	98	98	97
Acetone	1	1,400	1,100	1,400	1,300	1,300
	2	2,000	2,600	2,700	2,900	2,600
	3	4,000	4,100	4,300	4,100	4,100
2-Butanone	1	69	63	61	47	60
	2	140	140	140	130	140
	3	180	170	170	160	170
Chloroform	1	9.1	8.2	13	10	10
	2	16	17	22	29	21
	3	21	17	25	30	23
Benzene	1	ND	ND	ND	ND	ND
	2	5.5	4.9	6.9	6.3	5.9
	3	12	8.9	8.9	9.1	9.7
4-methyl-2 pentanone	1	10	9.7	ND	9.3	7.3
	2	21	24	19	23	22
	3	30	28	25	27	28
Toluene	1	32	29	45	41	37
	2	50	48	74	96	67
	3	70	59	97	130	89
Tetrachloroethylene	1	ND	ND	7.0	3.4	2.6
	2	5.0	4.5	7.3	10	6.7
	3	ND	ND	9.6	10	4.9
Ethylbenzene	1	ND	ND	ND	ND	ND
	2	4.2	34	4.0	4.6	12
	3	6.5	5.9	5.5	6.0	6.0

Table 4.8-11

Concentrations of Detected Target Analytes at the Tank Farm (cont.)

Target Analyte	Event	Concentration at Each Tank (ppb)				Average
		W	WC	E	S	
Total Xylenes	1	ND	ND	9.6	6.1	3.9
	2	26	25	25	31	27
	3	41	36	33	35	36
Hexachlorobutadiene	1	12	6.6	6.8	6.2	7.9
	2	9.5	9.2	11	14	11
	3	ND	ND	12	13	6.3
Bicycloheptadiene	1	ND	ND	ND	ND	ND
	2	30	28	33	49	35
	3	35	34	39	43	38
Dimethyl Disulfide	1	220	190	410	170	250
	2	1,200	1,200	1,700	910	1,300
	3	2,500	2,500	3,400	1,400	2,500
Dicyclopentadiene	1	82	70	110	95	89
	2	120	120	170	220	160
	3	85	88	130	150	110

ND = Not detected

* Event 1 = April 19, 1990

2 = July 18, 1990

3 = August 28, 1990

5.0 QUALITY ASSURANCE

The purpose of the QA program was to provide a set of guidelines for establishing and maintaining data quality that met the goals and objectives of the project. The two main areas of focus for the QA program were the development of the project organization and controls required to sustain data quality. Therefore, the QA program consisted of ongoing activities to establish quality control over field sampling events, laboratory measurement and data deliverables.

During the project planning and organization, before commencement of field sampling, the project manager designated a field team supervisor to coordinate activities. A set of SOPs was written to provide control and consistency throughout the field effort. Implementation of the procedures was ensured by the field team supervisor, and the Project Quality Assurance Coordinator (PQAC) was responsible for assuring that all field personnel were cognizant of the appropriate QA procedures. The laboratory was required to organize a management and analytical team as well. Initially, the laboratory designated a project manager to interface with the field project team. A laboratory QA coordinator (LQAC) was assigned by the laboratory to communicate to EBASCO QA personnel any analytical difficulties or other method problems. Lines of communication established at onset of the project, among the field, laboratory and QA personnel allowed the program to identify and resolve difficulties in a timely fashion.

General types of QA/QC functions for the IRA-F project included documentation review, observation of field procedures which were compared to good field practices (GFP) as prescribed in the SOPs, laboratory audits and review of analytical methodologies compared to written procedures. Quality assurance tasks also included review of "quality control" or QC samples, which were collected specifically to ensure that valid data were being collected. Specific types of QC samples collected under the IRA-F field program included field blanks, trip blanks, collocated samples and field spiking events. The laboratory QC functions, in addition to method QC requirements, included instrument tuning and calibration, standard matrix spikes and duplicates, method blanks and control charts.

The following procedures plus the project staff's dedication to quality helped assure sample quality, calculation accuracy, data integrity, and appropriate documentation for the soundest possible data package.

5.1 FIELD QUALITY PROGRAM

Quality control criteria were set up for the sampling instruments. The criteria set for the IRA-F field program were based on the Quality Assurance Handbook for Air Pollution Measurement Systems, "Ambient Air Specific Methods" (EPA-600/4-77/027a, 1985), to produce acceptable instrument performance. Whenever a flow rate or elapsed timer was outside acceptable limits, corrective action in the form of adjustment or maintenance was performed to bring the instrument within tolerance limits. Corrective actions and maintenance activities were documented in the daily logbooks.

5.2 QA/QC - CONTROL SAMPLES

As mentioned above, several types of samples were used to monitor the performance of both the sampling and analytical systems. The total number of QC samples taken was dependent on field conditions, the potential for contamination, and the total number of ambient samples for the project. As the project progressed and QC results became available, control sample requirements were changed to meet the needs of the project. In this section, analysis of the QC samples for Phase 1 and Phase 2 Odor Program is included along with the analyses of the Phase 3 and Phase 4 IRA-F program.

5.2.1 Field Blanks

A field blank was a sample of analyte-free media, identical to the sample matrix, which was passively exposed to the ambient environment at a representative sampling site and was otherwise handled in a manner identical to that of the regular samples. The field blank was used to assess contamination during all media handling procedures from the field to the laboratory. The number of samples taken equaled or exceeded five percent of the total number of samples taken over a sampling period. For example, if 500 samples were taken over a nine month period, a total of

25 field blanks were required to accompany samples at regular intervals. This requirement was satisfied for IRA-F by collecting a field blank for each media type for each sampling period. Consequently, field blank frequencies ranged from 12.5 to 20 percent for the various components of IRA-F, and were well above the specified requirements. Each blank was analyzed in a manner identical to that for the regular or ambient samples.

5.2.1.1 SVOC Field Blank Results

Table 5.2-1 lists the results for field blank analyses of SVOCs. All field blank results reported in the subsequent sections include an indication of the number of field blank samples, the number of detections of each analyte, the mean of the detections and the maximum detection, where appropriate. The blank sample results are reported as weights per filter and would need to be divided by the target sample volumes to compare to the ambient concentrations. Field blanks for Phases 1 and 2 were part of the Odor Program which was run concurrently with the Basin F remediation. Out of 15 field blanks analyzed under the Odor program, no target analytes were detected. A total of 56 field blanks were analyzed for Phases 3 and 4 under IRA-F. All 56 analyses exhibited no detections of target analytes. The total number of SVOC samples actually collected for IRA-F was 307. The number of field blanks was about 18 percent of the total number of samples collected and analyzed. Overall, the SVOC field blank analyses indicated that sample handling, shipping and laboratory analysis did not contaminate the samples.

5.2.1.2 OCP Field Blank Results

Results for the field blanks for OCP analysis are presented in Table 5.2-2. The OCP field blanks were not taken until Phase 2, Stage 2. Out of the four field blanks only one detection of ppDDT near the LCRL was found. A QA review of this field blank analysis determined that the detection of ppDDT in the field blank sample was suspect. The data from the lot of samples associated with the ppDDT containing field blank are not recommended for use. During Phase 3, 20 field blanks were analyzed and no detections of target analytes were found. A total of 56 field blanks were analyzed during Phase 4. Detections of Chlordane and Dieldrin were noted at levels near the LCRL. The laboratory discovered that during batch analysis a syringe used for

Table 5.2-1 SVOC Field Blank Results (µg)

		Compound											
Method: F7		Atrazine	Chlordane	CPMSO	CPMSO2	Dieldrin	Endrin	Isodrin	Malathion	ppDDE	ppDDT	Parathion	Supona
Detection Limit:		23	8.5	52	29	10	6.1	13	5.2	5.2	5.2	5.2	12
Phase 1	Mean	ND*	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Maximum	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Minimum	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	# Samples	1	1	1	1	1	1	1	1	1	1	1	1
	# Detections	0	0	0	0	0	0	0	0	0	0	0	0
Phase 2 Stage 1	Mean	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Maximum	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Minimum	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	# Samples	7	7	4	4	7	7	7	7	7	7	7	7
	# Detections	0	0	0	0	0	0	0	0	0	0	0	0
Phase 2 Stage 2	Mean	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Maximum	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Minimum	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	# Samples	7	7	7	7	7	7	7	7	7	7	7	7
	# Detections	0	0	0	0	0	0	0	0	0	0	0	0
Phase 3	Mean	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Maximum	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Minimum	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	# Samples	19	19	19	19	19	19	19	19	19	19	19	19
	# Detections	0	0	0	0	0	0	0	0	0	0	0	0
Phase 4	Mean	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Maximum	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Minimum	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	# Samples	16	16	16	16	16	16	16	16	16	16	16	16
	# Detections	0	0	0	0	0	0	0	0	0	0	0	0
Method: CM02		Atrazine	Chlordane	CPMSO	CPMSO2	Dieldrin	Endrin	Isodrin	Malathion	ppDDE	ppDDT	Parathion	Supona
Detection Limit:		4	12	6.2	4	4	4	7.6	5.1	15	4.7	N/A	4.2
Phase 4	Mean	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A	ND
	Maximum	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A	ND
	Minimum	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A	ND
	# Samples	21	21	21	21	21	21	21	21	21	21	N/A	21
	# Detections	0	0	0	0	0	0	0	0	0	0	N/A	0

* ND = Not Detected

CPMSO = P-Chlorophenylmethyl sulfoxide CPMSO2 = P-Chlorophenylmethyl sulfone ppDDE = p,p'-dichlorodiphenylethane

ppDDT = p,p'-dichlorodiphenyltrichloroethane

Table 5.2-2 OCP Field Blank Results (µg)

		Compound						
Method:	H7	Aldrin	Chlordane	Dieldrin	Endrin	Isodrin	ppDDE	ppDDT
Detection Limit:		0.1	0.101	0.1	0.1	0.1	0.1	0.1
Phase 1								
Mean		N/A	N/A	N/A	N/A	N/A	N/A	N/A
Maximum		N/A	N/A	N/A	N/A	N/A	N/A	N/A
Minimum		N/A	N/A	N/A	N/A	N/A	N/A	N/A
# Samples		0	0	0	0	0	0	0
# Detections		N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phase 2, Stage 1								
Mean		N/A	N/A	N/A	N/A	N/A	N/A	N/A
Maximum		N/A	N/A	N/A	N/A	N/A	N/A	N/A
Minimum		N/A	N/A	N/A	N/A	N/A	N/A	N/A
# Samples		0	0	0	0	0	0	0
# Detections		N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phase 2, Stage 2								
Mean		ND	ND	ND	ND	ND	ND	0.21
Maximum		ND	ND	ND	ND	ND	ND	0.21
Minimum		ND	ND	ND	ND	ND	ND	0.21
# Samples		4	4	4	4	4	4	4
# Detections		0	0	0	0	0	0	1
Phase 3								
Mean		ND	ND	ND	ND	ND	ND	ND
Maximum		ND	ND	ND	ND	ND	ND	ND
Minimum		ND	ND	ND	ND	ND	ND	ND
# Samples		20	20	20	20	20	20	20
# Detections		0	0	0	0	0	0	0
Phase 4								
Mean		ND	0.14	0.135	ND	ND	ND	ND
Maximum		ND	0.14	0.15	ND	ND	ND	ND
Minimum		ND	0.14	0.12	ND	ND	ND	ND
# Samples		56	56	56	56	56	56	56
# Detections		0	1	2	0	0	0	0

* ND = Not Detected

** N/A = Not a target analyte this phase

ppDDE = p,p'-dichlorodiphenylethane

ppDDT = p,p'-dichlorodiphenyltrichloroethane

spiking the surrogate had not been properly cleaned, resulting in contamination of all samples, including the field blank. The problem was disclosed on a corrective action form and distributed to the appropriate parties. These documents have been stored in the IRA-F project files. The analytical lot was placed in the "rejected file" at RMA and not used for the analyses in this report.

In general, the analyses of field blanks for OCP analytes indicated that adequate field and laboratory sample handling, shipping and analytical handling and extraction procedures were employed. All protocols employed were based upon the PMRMA's CQAP and were also included in the analytical methods (see Section 3.6).

5.2.1.3 Metals Field Blank Results

The results for the metals field blanks are listed on Table 5.2-3. During Phase 2, Stage 1, nine field blank samples were analyzed. One field blank detected zinc at 10 µg. Two of six field blanks analyzed during Phase 2, Stage 2, yielded detections of zinc at 6.7 and 73 µg. During Phase 3, eight field blanks were sampled. Three samples showed detections ranging from 7.3 to 64 µg of zinc. Out of 30 field blanks analyzed during Phase 4, zinc was detected 13 times at concentrations from 6 to 20 µg. Arsenic was detected twice during Phase 4 at concentrations of 1.4 and 2.6 µg, and lead was detected once at 11 µg.

The zinc detected in the field blanks was inherent in the type of filter media employed for the TSP sampling. IRA-F used EPM2000 filters manufactured by Whatman. The specifications on the filter include zinc at 10 to 100 µg per filter. This contamination was stated as being nonhomogeneous which accounts for the variance in zinc concentrations for field samples. Filter (background) zinc levels found in the analytical method blank were subtracted from the QC spikes but not from the actual sample concentration. Therefore all reported zinc values may be overestimates of actual concentrations and should be used with caution, including any lots that did not exhibit zinc contamination in the field blanks.

Table 5.2-3 Metals Field Blank Results (µg)

		Compound					
Method: G7		Arsenic	Cadmium	Chromium	Copper	Lead	Zinc
Detection Limit:		0.625	0.648	8.36	14.2	8.19	5.65
Phase 1	Mean	N/A	N/A	N/A	N/A	N/A	N/A
	Maximum	N/A	N/A	N/A	N/A	N/A	N/A
	Minimum	N/A	N/A	N/A	N/A	N/A	N/A
	# Samples	0	0	0	0	0	0
	# Detections	N/A	N/A	N/A	N/A	N/A	N/A
Phase 2 Stage 1	Mean	ND	ND	ND	ND	ND	10
	Maximum	ND	ND	ND	ND	ND	10
	Minimum	ND	ND	ND	ND	ND	10
	# Samples	9	9	9	9	9	9
	# Detections	0	0	0	0	0	1
Phase 2 Stage 1	Mean	ND	ND	ND	ND	ND	39.9
	Maximum	ND	ND	ND	ND	ND	73
	Minimum	ND	ND	ND	ND	ND	6.7
	# Samples	6	6	6	6	6	6
	# Detections	0	0	0	0	0	2
Phase 3	Mean	ND	ND	ND	ND	ND	27.1
	Maximum	ND	ND	ND	ND	ND	64
	Minimum	ND	ND	ND	ND	ND	7.3
	# Samples	8	8	8	8	8	8
	# Detections	0	0	0	0	0	3
Phase 4	Mean	2	ND	ND	ND	11	10.6
	Maximum	2.6	ND	ND	ND	11	20
	Minimum	1.4	ND	ND	ND	11	6
	# Samples	30	30	30	30	30	30
	# Detections	2	0	0	0	1	13

* ND = Not Detected

** N/A = Not a target analyte this phase

There was one detection of lead and two detections of arsenic near the LCRL for the method. These were possibly due to noise factors, drift in instrumentation or laboratory contamination. Since these levels were low, they did not appear to affect investigative sample results. A total of 38 field blanks were analyzed during Phases 3 and 4. Samples collected during that period totaled 264, and the number of field blanks was 14 percent of the total.

5.2.1.4 Mercury Field Blank Results

Results for mercury field blank analysis are presented in Table 5.2-4. No mercury sampling was conducted under the Odor Program during Phase 1. During Phase 2, six field blanks were analyzed for each stage, and no mercury was observed in any of these field blanks. In Phase 3, 16 field blanks were analyzed, and again mercury was not detected in these blanks. During Phase 4, 27 field blanks were analyzed. Two of these blanks contained levels of mercury at 0.14 and 0.13 μg , which were near the LCRL of the method (0.0889 μg). All actual samples collected on the same days as the field blank detections contained values at less than (LT) the LCRL or concentrations similar to the 0.173 μg of the blanks. The LT concentrations were less than the blank's levels and can be used with confidence. Sample values near the blank levels should not be used as there may have been contamination in the analytical system.

The system for analyzing mercury samples was a CVAAS. The closed loop system employed by MRI and could easily become contaminated when concentrations near the high spike (1.0 μg) are analyzed through the system. The amount retained in the system is usually small, but blanks continue to be analyzed until the system becomes uncontaminated. There were 264 mercury samples collected during Phases 3 and 4. Field blanks numbered 33, or nearly 13 percent of the total samples collected.

5.2.1.5 Volatile Organic Compounds Field Blank Results

The results for VOC field blank analyses are presented on Table 5.2-5. During Phase 1 only one field blank was collected that contained 0.067 μg of benzene and 0.15 μg of methylene chloride.

Table 5.2-4 Mercury Field Blank Results (μg)

Method: J7		Mercury
Detection Limit:		0.089
Phase 2		
Stage 1	Mean	ND
	Maximum	ND
	Minimum	ND
	# Samples	6
	# Detections	0
Phase 2		
Stage 2	Mean	ND
	Maximum	ND
	Minimum	ND
	# Samples	6
	# Detections	0
Phase 3		
	Mean	ND
	Maximum	ND
	Minimum	ND
	# Samples	16
	# Detections	0
Phase 4		
	Mean	0.0135
	Maximum	0.14
	Minimum	0.13
	# Samples	27
	# Detections	2

* ND = Not Detected

** N/A = Not a target analyte this phase

Table 5.2-5 VOC Field Blank Results (µg)

		Compound										
Method:	E7	111TCE	112TCE	11DCLE	12DCLE	12DMB	BCHPD	C6H6	CCL4	CH2CL2	CHCL3	CLC6H5
Detection Limit:		0.0175	0.0085	0.007	0.006	0.008	0.012	0.007	0.013	0.008	0.006	0.0095
Phase 1	Mean	N/A**	ND*	N/A	ND	N/A	ND	0.067	ND	0.148	ND	ND
	Maximum	N/A	ND	N/A	ND	N/A	ND	0.067	ND	0.148	ND	ND
	Minimum	N/A	ND	N/A	ND	N/A	ND	0.067	ND	0.148	ND	ND
	# Samples	0	1	0	1	0	1	1	1	1	1	1
	# Detections	N/A	0	N/A	0	N/A	0	1	0	1	0	0
Phase 2 Stage 1	Mean	ND	ND	ND	0.045	ND	ND	0.064	0.055	0.126	0.021	0.028
	Maximum	ND	ND	ND	0.074	ND	ND	0.116	0.1	0.2	0.031	0.028
	Minimum	ND	ND	ND	0.015	ND	ND	0.037	0.027	0.014	0.011	0.028
	# Samples	1	8	1	8	1	8	8	8	7	8	8
	# Detections	0	0	0	2	0	0	8	3	7	2	1
Phase 2 Stage 2	Mean	ND	ND	ND	0.0099	ND	ND	0.0146	0.21	0.078	ND	ND
	Maximum	ND	ND	ND	0.0099	ND	ND	0.019	0.21	0.21	ND	ND
	Minimum	ND	ND	ND	0.0099	ND	ND	0.0098	0.21	0.035	ND	ND
	# Samples	5	5	5	5	5	5	5	5	5	5	5
	# Detections	0	0	0	1	0	0	3	1	5	0	0
Phase 3	Mean	0.045	ND	ND	ND	0.062	ND	0.0242	0.018	0.063	ND	ND
	Maximum	0.045	ND	ND	ND	0.1	ND	0.0723	0.018	0.2	ND	ND
	Minimum	0.045	ND	ND	ND	0.024	ND	0.0072	0.018	0.017	ND	ND
	# Samples	21	21	21	21	21	21	21	21	21	21	21
	# Detections	1	0	0	0	2	0	16	1	12	0	0
Phase 4	Mean	ND	ND	ND	ND	0.014	ND	0.0321	ND	0.074	ND	ND
	Maximum	ND	ND	ND	ND	0.014	ND	0.09	ND	0.24	ND	ND
	Minimum	ND	ND	ND	ND	0.014	ND	0.0076	ND	0.012	ND	ND
	# Samples	54	54	54	54	54	54	54	54	54	54	54
	# Detections	0	0	0	0	1	0	36	0	18	0	0
Method:	E7	DBCP	DCPD	DMDS	ETC6H5	MEC6H5	MIBK	NNDMEA	T12DCE	TCLEE	TRCLE	XYLEN
Detection Limit:		0.011	0.013	0.0135	0.0085	0.023	0.005	0.0295	0.0115	0.0095	0.015	0.0405
Phase 1	Mean	ND	ND	N/A	ND	ND	ND	ND	ND	ND	ND	ND
	Maximum	ND	ND	N/A	ND	ND	ND	ND	ND	ND	ND	ND
	Minimum	ND	ND	N/A	ND	ND	ND	ND	ND	ND	ND	ND
	# Samples	1	1	0	1	1	1	1	1	1	1	1
	# Detections	0	0	N/A	0	0	0	0	0	0	0	0
Phase 2 Stage 1	Mean	ND	ND	ND	ND	0.083	ND	ND	ND	ND	ND	ND
	Maximum	ND	ND	ND	ND	0.12	ND	ND	ND	ND	ND	ND
	Minimum	ND	ND	ND	ND	0.043	ND	ND	ND	ND	ND	ND
	# Samples	8	8	1	8	8	8	8	8	8	8	8
	# Detections	0	0	0	0	4	0	0	0	0	0	0
Phase 2 Stage 2	Mean	ND	ND	ND	ND	0.23	ND	ND	ND	ND	ND	ND
	Maximum	ND	ND	ND	ND	0.23	ND	ND	ND	ND	ND	ND
	Minimum	ND	ND	ND	ND	0.23	ND	ND	ND	ND	ND	ND
	# Samples	5	5	5	5	5	5	5	5	5	5	5
	# Detections	0	0	0	0	1	0	0	0	0	0	0
Phase 3	Mean	0.097	0.016	ND	0.056	0.101	0.026	ND	ND	0.1	ND	0.129
	Maximum	0.097	0.016	ND	0.094	0.143	0.026	ND	ND	0.1	ND	0.2
	Minimum	0.097	0.016	ND	0.017	0.031	0.026	ND	ND	0.1	ND	0.058
	# Samples	21	21	21	21	21	21	21	21	21	21	21
	# Detections	1	1	0	2	5	1	0	0	1	0	2
Phase 4	Mean	ND	ND	ND	ND	0.084	ND	ND	ND	ND	ND	ND
	Maximum	ND	ND	ND	ND	0.139	ND	ND	ND	ND	ND	ND
	Minimum	ND	ND	ND	ND	0.029	ND	ND	ND	ND	ND	ND
	# Samples	54	54	54	54	54	54	54	54	54	54	54
	# Detections	0	0	0	0	2	0	0	0	0	0	0

* ND = Not Detected

** N/A = Not An Analyte This Phase

111TCE = 1,1,1-trichloroethane 112TCE = 1,1,2-trichloroethane 11DCLE = 1,1-dichloroethane 12DMB = 1,2-dimethyl benzene

BCHPD = bicycloheptadiene C6H6 = benzene CCL4 = Carbon tetrachloride CH2CL2 = methylene chloride CHCL3 = chloroform

CLC6H5 = chlorobenzene DBCP = dibromochloropropane DCPD = dicyclopentadiene DMDS = dimethyl disulfide

ETC6H5 = ethyl benzene MEC6H5 = toluene MIBK = methyl isobutyl ketone NNDMEA = n-nitrosodimethylamine

T12DCE = trans-1,2-dichloroethene TCLEE = tetrachloroethylene TRCLE = trichloroethylene XYLEN = xylene

The methylene chloride concentration was above the upper certified limit (UCRL) of 0.100 µg, and was considered an estimated value.

During Phase 2, Stage 1 there were eight field blanks collected. Analyses showed contamination with 1,2-dichloroethane, benzene, carbon tetrachloride, chloroform, chlorobenzene and toluene, ranging from 0.011 µg to 0.126 µg. Concentrations for field samples from this phase should be used with caution. In Stage 2 of Phase 2 five field blanks were collected. Detections of 1,2-dichloroethane, benzene, carbon tetrachloride, methylene chloride and toluene were noted at least once. Concentrations ranged from 0.0099 µg (near the LCRL) to 0.23 µg (above the UCRL).

During Phase 3, a total of 21 field blanks were collected. Analyses indicated detections of 111TCE, 12DMB, benzene, carbon tetrachloride, methylene chloride, dibromochloropropane, dicyclopentadiene, ethyl benzene, toluene, methyl isobutyl ketone, tetrachlorethylene and xylene. Out of 22 target analytes, 12 analytes were detected at least once. Concentrations ranged from 0.016 to 0.2 µg, which was above the UCRL limit of 0.100 µg. Sample values during this phase which were observed near the LCRL should be used with caution.

Phase 4 sampling included 54 field blank samples. Analyses indicated detections of 12DMB, benzene, methylene chloride and toluene. Concentrations ranged from 0.0076 to 0.24 µg (above the UCRL). A single laboratory analyzed all samples from Phase 1 through Phase 4 using a PMRMA certified Method E-7 (refer to Section 3.6). The media employed for sample collection was Tenax and Tenax-and-charcoal. Tenax is known to degrade to benzene at temperatures in excess of 200° C. During analysis each tube was thermally desorbed to 200° C, therefore, small detections of benzene were unavoidable with this method. Methylene chloride is the most common solvent for organic sample extraction and is easily adsorbed into the Tenax-and-charcoal. High concentrations of methylene chloride, above the UCRL, could occur if the laboratory stored, handled or temporarily placed Tenax tubes near the solvent. All methylene chloride and benzene detections from Phases 1 through 4 should be used with caution.

Other sources for the contamination of field blanks may include vehicle engine emissions from site visits, refrigerator coolants and off-gasing of shipping materials. Often the reason for contamination cannot be thoroughly explained. Although caution should be implemented for certain phases and compounds, it is necessary for the data user to judge whether the values fit into historical data or the predicted modeling patterns.

There were 485 field samples taken during Phases 3 and 4 for the VOC analyses. A total of 75 field blanks were collected making up 15 percent of the total.

5.2.2 Trip Blanks

Trip blanks were collected as part of the overall QC program. A trip blank is a single unit of analyte-free media shipped from the laboratory to the sample preparation site, then returned to the laboratory unopened. The purpose of the trip blank was to document any contamination which might be attributed to shipping and field transportation procedures.

Trip blanks of media for each group of analytes including; metals and arsenic, mercury, SVOCs and OCPs were shipped on May 10, 1989, during Phase 3 of the IRA-F. All but one of the analyses for target analytes were below the LCRL, indicating that no contamination occurred during shipping and handling. The one exception was a zinc detection, which was not unexpected because zinc was a known contaminant within the actual sampling filter media.

Four trip blanks for VOCs were analyzed during Phase 1. All four exhibited detections of benzene ranging from 0.05 µg to 0.140 µg. These values ranged from within the certified range to above the upper CRL for benzene. However, Tenax is known to decompose at 200° C to form benzene. Detections of benzene were expected to occur during desorption of Tenax traps. Discovery of benzenes is normally not due to contamination of Tenax from outside sources. Two out of the four trip blanks also detected methylene chloride, a common laboratory contaminant.

Two VOCs trip blanks were analyzed during Phase 3 of the IRA-F program. Both exhibited detection of benzene. One yielded detections of not only methylene chloride, but of toluene and methyl isobutyl ketone. The latter two contaminants were possibly related to laboratory operations, but were not considered to be common or continual contaminants.

Overall, trip blank analyses indicated good sample handling and shipping. Apparent VOC contamination could be attributed to other sources. The precautions necessary in using the VOC data are discussed in Section 5.5.

5.2.3 Collocated Samples

Collocated samples are samples taken independently, but collected at the same height within two to four meters horizontal distance from one another. One sample was designated as the primary sample and the other was designated as the collocated sample. The objective was to compare what were essentially duplicate samples and results. These samples were used to document the precision of the sampling and analytical processes. Collocated samples were collected for approximately five percent of the total number of samples taken during the sample period. This requirement was satisfied by the collection of collocated SVOC/OCP and VOC samples during every other SVOC/OCP and VOC sample episode, and collocated mercury and TSP/metals for every sample episode. Collocated samples were compared and the percent difference between them was calculated.

Individual data pairs for all collocated samples are provided in Appendix F for each target analyte. Included in Appendix F is a listing of the concentrations for site FC-2 and FC-2D and a percent difference for the sample pair, based on the guidance provided in 40 CFR 58 Appendix B. A synopsis for the collocated data for each analyte is provided in Table 5.2-6, including the number of valid pairs, the mean percent differences, and the standard deviation for each analyte. The calculated upper and lower 95 percent confidence limits (in terms of percent difference) are also provided.

Table 5.2-6 Collocated Sample Results

ANALYTE	No. of Valid Pairs	Mean Percent Difference	Standard Deviation	Confidence - 95%	Limits +95 %
Aldrin	12	9.4	52.6	-93.7	112.5
Chlordane	11	1.8	10.8	-19.3	22.9
Dieldrin	35	-2.6	30.0	-61.3	56.2
Endrin	24	-2.9	10.9	-24.3	18.4
Arsenic	12	-0.3	18.7	-36.9	36.4
Cadmium	7	2.2	34.8	-66.1	70.3
Copper	36	12.2	45.3	-76.6	101.1
Lead	27	-3.1	25.6	-53.3	47.2
Zinc	37	-2.6	16.1	-34.1	28.9
TSP	41	2.1	5.8	-9.3	13.5
1,1,1-Trichloroethane	38	-1.0	43.3	-85.8	83.9
1,2-Dichloroethane	17	-2.9	37.6	-76.6	70.7
o-xylene	37	-6.5	64.7	-133.3	120.2
Bicycloheptadiene	8	6.9	24.9	-42.0	55.7
Benzene	35	0.4	54.1	-105.8	106.5
Carbon tetrachloride	37	5.1	27.4	-48.5	58.7
Methylene chloride	35	-3.5	36.6	-70.2	68.1
Chloroform	37	5.8	46.0	-84.4	96.0
Ethylbenzene	37	-5.6	59.9	-123.1	111.9
Toluene	26	-11.6	53.0	-115.3	92.2
Methyl isobutyl ketone	13	22.7	41.1	-57.9	103.4
Tetrachloroethene	37	-5.8	32.4	-69.3	57.8
Trichloroethene	9	-0.9	19.4	-39.0	37.2
m and p-xylene	33	-1.2	56.6	-112.2	109.8
Total xylenes	37	-7.2	62.1	-128.9	114.5

5.2.3.1 SVOC Collocated Samples

None of the SVOC target analytes was detected for the primary and collocated samples during the IRA-F project. Assessment of the precision and accuracy of these sampling efforts cannot be completed without detected values.

5.2.3.2 OCP Collocated Samples

A total of 39 pairs of collocated OCP samples was collected and analyzed under the IRA-F program. The number of valid pairs for each analyte depended upon the valid detection of concentrations within the certified range. For Aldrin, most of the number of valid detections were within 25 percent of the sample means, as shown in Appendix F. For one case (May 22, 1989) a 40 percent difference was calculated, but sample detections were very near the LCRL. For another case (September 2, 1990) a wide discrepancy was observed, and the data pair must be discarded as an anomaly. Chlordane and Endrin pairs all show remarkable consistency, and all but one each of the pairs for Dieldrin and Isodrin was within 25 percent of the sample mean. Despite these anomalous readings, the OCP collocated data indicated excellent field sampling and analytical precision.

5.2.3.3 Metals Collocated Samples

A total of 38 valid pairs of collocated samples for metals was collected. Of these copper and zinc were detected in nearly all samples (36 and 37 valid pairs, respectively), and chromium was not detected in any sample pairs. For arsenic and cadmium the collocated data compared favorably, with percent recoveries within 25 percent for all but three samples. Analyses of these three samples reported concentrations just above the LCRL, and the percent recoveries were anomalous for such situations. For copper, there is a relatively large standard deviation of percent differences, indicating that individual values must be used with caution. The lead and zinc data showed greater consistency, with only three separate pairs having a percent difference greater than 50 percent. It has already been noted in this section that zinc data must be used with caution because of the relatively high background levels detected in the field blanks.

Copper was not a known contaminant within the filter media. Two possibilities exist to explain the observed patterns. Copper contamination could have occurred due to wear of the brass hold-down fittings for the filter frame. The filter frame was secured in the sampler by four brass bolts with brass wing nuts. Motor vibration during sampling and wear during installation may have caused the production of small brass shavings which may have been drawn onto the filter and subsequently analyzed as ambient concentrations. Secondly, the analytical instrumentation was not as sensitive to copper as to other metals, part of which is evidenced by higher LCRL values for copper than for other metals. Copper contamination was not seen in the field blanks, as was noted above.

5.2.3.4 TSP Collocated Samples

A total of 41 pairs of TSP collocated samples were collected and all were used in this comparison. One of the sample pairs (March 18, 1990) had reported TSP concentrations below $20 \mu\text{g}/\text{m}^3$, and this pair could have been disregarded based on EPA guidance, but it was not. The mean percent difference for TSP (2.1 percent) and the upper and lower 95 percent confidence limits (13.5 percent and -9.3 percent) provided assurance that there were no errors of any consequence in sampling or analyses for TSP.

5.2.3.5 VOC Collocated Samples

A total of 41 pairs of Tenax and Tenax-and-charcoal pairs was collected under IRA-F. Valid pairs were determined from the sum of the collected sample mass from both tubes for each sample. For this comparison, both the data within the certified range and those estimated values above the UCRL were used for comparison. The estimated values are known to be less accurate than the certified data, and therefore, the collocated results with estimates must be viewed as less precise than those with certified data only. An important comparison for the VOC data is the number (or percent) of valid samples with percent differences above 50 percent.

As an example, for 111TCE, two of the 38 pairs had percent differences above 100 percent and two more pairs had differences of more than 50 percent. The remainder of the results were

remarkably consistent. The remainder of the target VOCs data in Appendix F must be examined with the same cautions. The relatively large standard deviations for 1,2-dimethyl benzene, benzene and (o-xylene) were probably due to a large number of values above the UCRL. The results point out that caution must be used when analyzing the VOC data, especially with results which were above the UCRL. For all but two analytes, the mean percent differences were within 10 percent. For most VOC analytes, the high standard deviations were the result of a few extremely high numbers, while the vast majority of differences were less than 50 percent. The results indicated that most VOC data were reliable and precise, but the occasional high values must be used with caution.

5.2.4 Spiked Samples

A spiked sample was a unit of analyte-free media to which a known concentration of target analyte(s) was (were) added. Introduction of the spiking solution was accomplished immediately prior to activation of the sampler. Once the media had been spiked, the sampler was started and the sample was aerated as a regular sample; and it was otherwise handled routinely during reclamation and analysis.

Spiking was performed to assess the efficiency of sampling and analysis, based on the percentage recovery of the known spiking analyte. Spiked samples were taken as determined by QC personnel, but normally they were collected once per season to provide data on percent recovery and possible compound degradation of analytes during different weather conditions. Actual spiking procedures may be found in Appendix A.

A total of nine spiking events were performed under the IRA-F project. Two sets were judged invalid due to laboratory error. Of the remaining data sets, two were spiked with a mixture of SVOCs, four were spiked with an OCP mixture, and one was spiked with a mixture containing all of the target VOCs.

The basic validity of the sampling methods depends greatly on the detailed research and analyses which went into the method development. Spiking was done for informational purposes, and the results cannot be used to negate or weaken the results of the sampling program. Field spiking with a liquid solution and subsequent aeration of the spiking liquid are not similar to the adsorption of vapors onto the sample medium. The technique provided information on what happened to liquids which were placed on a filter media and then aerated for 24-hours. In many cases the liquids were not adsorbed onto the media in the same manner as vapors, and media aeration simply evaporated the liquid spike. In addition the spiking solvent may have acted to strip any adsorbed vapors from the medium or it may have interfered with that adsorption. Consequently, the spiking results cannot be used to judge the validity of the sampling program or to adjust the data.

Each spiking event employed a control sample, a field matrix spike and a field matrix spike duplicate. The control sample was the sample used to identify any background levels of target analytes to be subtracted from the amounts of analytes detected in the actual spikes. The matrix spikes were performed in duplicate to furnish precision as well as accuracy data. Tables 5.2-7 through 5.2-9 list the dates, the spiking amounts and the spike results for the IRA-F project.

Spike samples of SVOCs indicated the loss of Isodrin. Respective recoveries for all other analytes averaged between 70 and 140 percent, with the exception of CPMSO₂, which was near 50 percent. Some recoveries near 200 percent were evident for the 500 µg spike. At this level the analytical system was near capacity and may have given falsely high results. In general, analytical recoveries and collection efficiencies of 75 percent are considered to be acceptable (EPA, 1984). The amount of spiked analyte was chosen to fall at mid-range and near the upper range of the certified concentrations to demonstrate that the method was capable of providing adequate recoveries for the target analytes of varying concentrations. The OCP spiking results indicated the loss of Aldrin, Chlordane and Isodrin at low levels. The Aldrin loss is documented by the EPA in Method T0-4 of the Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air (EPA-600/4-84-041, April, 1984). In actual field sampling

Table 5.2-7 SVOC Spiking Recoveries

August 28, 1989 Target Analyte (500 µg Added)	Control Sample Concentration (µg)	Primary Sample Concentration (%)	Primary Sample Concentration (µg)	Collocated Sample Concentration (%)	Collocated Sample Concentration (µg)
Atrazine	LT*	193%	966	193%	966
Chlordane	LT	102%	512	102%	512
CPMSO	LT	200%	1000	200%	1000
CPMSO ₂	LT	123%	613	147%	735
Dieldrin	LT	109%	547	123%	616
Endrin	LT	92%	459	92%	459
Isodrin	LT	9%	44	14%	69
Malthion	LT	118%	590	118%	590
Parathion	LT	124%	620	124%	620
ppDDE	LT	111%	557	111%	557
ppDDT	LT	115%	577	115%	577
Supona	LT	125%	627	125%	627

May 25, 1990 Target Analyte (50 µg Added)	Control Sample Concentration (µg)	Primary Sample Concentration (%)	Primary Sample Concentration (µg)	Collocated Sample Concentration (%)	Collocated Sample Concentration (µg)
Atrazine	LT	84%	42	82%	41
Chlordane	LT	102%	51	100%	50
CPMSO	LT	58%	29	48%	24
CPMSO ₂	LT	96%	48	92%	46
Dieldrin	LT	110%	55	106%	53
Endrin	LT	86%	43	84%	42
Isodrin	LT	0%	LT	0%	LT
Malthion	LT	80%	40	74%	37
ppDDE	LT	112%	58	106%	53
ppDDT	LT	80%	40	78%	39
Supona	LT	92%	46	88%	44

* LT = Less than the lower certified reporting limit (LCRL)

ppDDE = p,p'-dichlorodiphenylethane

ppDDT = p,p'-dichlorodiphenyltrichloroethane

CPMSO = P-chlorophenylmethyl sulfoxide

CPMSO₂ = P-chlorophenylmethyl sulfone

Table 5.2-8 OCP Spiking Recoveries

June 23, 1989 Target Analyte (1 µg Added)	Control Sample Concentration (µg)	Primary Sample Concentration (%)	Primary Sample Concentration (µg)	Collocated Sample Concentration (%)	Collocated Sample Concentration (µg)
Aldrin	LT*	0%	LT	11%	0.112
Chlordane	LT	18%	0.182	20%	0.198
Dieldrin	LT	90%	0.897	10%	0.103
Endrin	LT	93%	0.937	98%	0.981
Isodrin	LT	13%	0.130	18%	0.183
ppDDE	LT	96%	0.957	95%	0.952
ppDDT	LT	92%	0.916	93%	0.929

March 15, 1990 Target Analyte (1.8 µg Added)	Control Sample Concentration (µg)	Primary Sample Concentration (%)	Primary Sample Concentration (µg)	Collocated Sample Concentration (%)	Collocated Sample Concentration (µg)
Aldrin	LT	0%	LT	0%	LT
Chlordane	0.11	99%	1.9	88%	1.7
Dieldrin	0.85	92%	2.5	86%	2.4
Endrin	0.19	95%	1.9	95%	1.9
Isodrin	LT	0%	LT	0%	LT
ppDDE	LT	100%	1.8	94%	1.7
ppDDT	LT	106%	1.9	94%	1.7

* LT = Less than the certified reporting limit (CRL)

ppDDE = p,p'-dichlorodiphenylethane

ppDDT = p,p'-dichlorodiphenyltrichloroethane

Table 5.2-9 VOC Spiking Recoveries

June 6, 1990						
Target Analyte (0.200 µg Added)	Control T/T+C (µg)	Primary T/T+C (%)	(µg) *	Secondary T/T+C (%)	(µg) *	
1,1,1-trichloroethane	0.2	5%	0.01	5%	0.01	
1,1,2-trichloroethane	LT**	42%	0.083	51%	0.102	
1,1-dichloroethane	LT	50%	0.1	50%	0.1	
1,2-dichloroethane	0.023	43%	0.0868	43%	0.086	
1,1-dimethyl benzene	0.068	0%	LT	16%	0.032	
BCHPD	LT	27%	0.054	25%	0.05	
Benzene	0.2	0%	LT	0%	0	
Carbon tetrachloride	0.103	15%	0.029	24%	0.047	
Methylene chloride	0.1	0%	0	0%	LT	
Chloroform	0.2	0%	0	0%	0	
Chlorobenzene	0.012	0%	LT	0%	LT	
DBCP	LT	0%	LT	0%	LT	
DCPD	LT	0%	LT	20%	0.039	
DMDS	LT	68%	0.136	61%	0.121	
Ethylbenzene	0.046	0%	LT	27%	0.054	
Toluene	0.123	0%	0	0%	0	
MIBK	LT	36%	0.071	50%	0.1	
NNDMEA	LT	28%	0.055	40%	0.079	
Trans-1,2-dichloroethylene	LT	50%	0.1	50%	0.1	
Tetrachloroethylene	0.1	15%	0.03	12%	0.053	
Trichloroethane	LT	43%	0.086	27%	0.053	
Xylene	0.24	0%	0	0%	0	

* Amounts in this column are detected amount minus amount in control sample.

** LT = Less than the lower certified reporting limit (LCRL).

T = Tenax

T+C = Tenax-and-charcoal

BCHPD = bicycloheptadiene

DBCP = dibromochloropropane

DCPD = dicyclopentadiene

MIBK = methyl isobutyl ketone

NNDMEA = n-nitrosodimethylamine

there is a potential for stripping or oxidation of Aldrin. Isodrin is chemically similar and reacts, when aerated, like Aldrin. These chemical characteristics confirm the field spike results. Chlordane is a complex mixture of individual compounds. A specific isomer, gamma Chlordane, was used in the OCP method for simplicity. Hence, the overall recovery of the Chlordane mixture is unknown. Recoveries of the other target analytes were above 90 percent, and provided acceptable results for the spiking efforts.

Spiking with VOCs was performed on June 6, 1990. The complete target analyte list for VOCs was used to identify compounds to be utilized in the spike. The spike was applied directly onto a Tenax and Tenax-and-charcoal tube train.

Results showed that many of the compounds were possibly not suited for this spiking method. One compound with LT amounts for control samples and spikes alike was DCPD, which was apparently not trapped or not retained on the Tenax medium. Targets with zero percent recovery were those compounds that were not detected at high, or similar levels in the control sample. This does not indicate poor recoveries or poor suitability. For example, benzene was detected in the control sample at 0.2 µg, while 0.2 µg was spiked onto the tube trains, but none was detected on the spiked sample during analysis. The UCRL for the method was 0.1 µg, making all values greater than the CRL allowed. Since volatility of the VOCs is difficult to contain or control, the in-laboratory results vary more than the more stable VOC methods. Expectations for recoveries may be near 50 percent as seen for the IRA-F program. Little information is available for comparison as ambient air analysis is still under development. More field spike data is necessary to set criteria and recognize trends.

The purpose for field spiking was to assess the real-time use of guidance methodologies and their appropriate application toward specific contaminants. The information developed from the IRA-F spiking events will allow the Army program to develop alternatives to the present methods wherever the methods did not fulfill the suitability requirements.

5.3 AUDIT PROGRAM

The purpose of the audit program was to ensure that field and laboratory activities conformed to project and RMA requirements, and that they were effectively implemented, and that problems or deficiencies were promptly resolved.

Field and laboratory audits of operations and overall QA implementation were performed through system and performance audits. Each sampler in the sampling network was evaluated during every quarterly audit performed for the project QA program. The meteorological system operated by the CMP was also audited. The QA oversight role included an in-depth review which was usually performed on an annual basis, allowing for changes in the program to fit project needs. Performance audits investigated day-to-day activities and compared them to written procedures.

Audit teams were composed of trained technical personnel who were independent of any project-related responsibilities. After each audit, an informal close-out meeting allowed the audit team to discuss findings with field or laboratory personnel. An audit report documented the findings and proposed immediate or long-term corrective actions for any problems. This report was sent to project management and any other project personnel requiring the information. All audits were performed according to the CQAP version 1.0, 1989, IRA-F QA Plan, and approved field and laboratory practices.

5.3.1 Field Operations

Independent performance audits of field operations and sampling procedures were conducted quarterly by staff from the EBASCO Atlanta office. Equipment checks and procedures were reviewed for operation performance and compliance with standard operating procedures. All five audits concluded that equipment was operating well and that proper calibration methods were utilized. Small immediate corrective actions were taken for worn tubing, dirty equipment and the inclusion of any procedures recommendations into the daily routine.

One field document audit was performed during the IRA-F program in July 27, 1989. The audit consisted of reviewing field document preparation and storage. Conclusions from the audit stated that the IRA-F field team provided good documentation of sampling events, transfer of samples to the laboratory, and maintained an adequate and orderly filing system.

5.3.2 Laboratory Audits

Quarterly audits were performed on all laboratories participating in analyzing RMA samples. During the IRA-F program, Midwest Research Institute (MRI) was the only laboratory employed to analyze air samples. The MRI laboratory was PMRMA certified for SVOCs, VOCs, metals and mercury analyses, and also performed TSP and PM-10 analyses which did not require certification.

The audit team consisted of representatives from the QA section of the LSD from RMA, Shell, and other RMA contractors whose samples from other programs were sent to MRI for analysis. The audit consisted of addressing problems from the laboratory and contractors, reviewing specific method applications or inconsistencies or deficiencies in data or sampling, and reviewing data packets for traceability, appropriate documentation, and completeness. Laboratory personnel were available to answer questions and describe analytical or data reduction techniques.

5.4 QUALITY CHECKS ON NONTARGET COMPOUNDS

Nontarget compounds, as described in Section 4.0, were further evaluated by dividing TICs into similar compound groups (i.e., hydrocarbons, isomers of benzene-related compounds, esters, chlorinated-fluorinated compounds and oxygen containing compounds). The number of detections, the maximum estimate found, and the average estimate of all detections were then determined. Classification was done for GC/MS analyses of both VOC and SVOC methods.

5.4.1 Nontarget VOCs

One trip blank for the IRA-F project was examined for nontarget VOCs. Hydrocarbons, chlorofluorocarbons (CFCs), oxygenated hydrocarbons, and terpenes were detected at estimated

levels from 0.01 to 0.1 µg per VOC trap set. Although these detected compounds are considered common contaminants, in theory they should not have been present on a trip blank. The particular VOC tubes employed during the IRA-F program were individually checked at the laboratory for contamination before shipment to the field site. The tubes were pyrex glass, and were sealed with stainless steel swage-lock fittings equipped with Teflon O-rings. It was possible to crush the glass tube if too much pressure was applied to the fitting, or if the glass had even a small defect. Due to this restriction, the fittings could only be tightened by hand, and a good, positive seal could be difficult to attain. A poor seal might have allowed contaminants to enter the trap.

Five field blanks were examined for nontarget VOCs. The chemical groups detected were similar to those found in the trip blank with the addition of various benzene containing compounds (i.e. naphthalene and C₃-benzenes). Concentration levels ranged from 0.01 to 0.20 µg per tube set. In general contaminants did not vary in chemical groupings and were fairly consistent in concentrations. Summaries of the nontarget VOC field blanks results are presented in Tables 5.4-1 and 5.4-2, and summaries of trip blank results are presented in Tables 5.4-3 through 5.4-8.

Approximately 32 VOC sample sets were analyzed and examined for nontargets. Actual samples contained many of the trip and field blank contaminants in addition to real-time TICs. The bulk of the chemical groupings detected, such as aldehydes, alkanes, alkenes, ketones and aromatics were due to the urban airshed and were not necessarily a major concern. Other compounds such as silanes and acetone are known common laboratory contaminants.

Specific compounds such as cineole, camphor and certain terpenes are not naturally occurring, but are usually synthesized for manufacturing various types of products (i.e. plastics, lacquers, fragrances and solvents). Methyl T-butyl ether was detected only once, on December 16, 1989, but was the oxy-fuel additive to unleaded gasoline used during the winter months in Denver.

Table 5.4-1 Summary of Phases 1 and 2 Nontarget VOC Field Blank Detections
Tenax Media ($\mu\text{g}/\text{sample}$)

Compound	No. of Detections	24-Hour Maximum	Mean
Acetone	6	0.340	0.126
Aliphatic hydrocarbons	4	0.033	0.019
Alkanes	19	0.072	0.036
Alkenes	1	0.010	0.010
Benzaldehydes	2	0.040	0.040
Benzenes	7	0.043	0.022
Chlorofluorocarbons	10	0.970	0.347
Cyclohexane	2	0.040	0.025
Hexane	9	0.200	0.092
Methyl benzoate	1	0.012	0.012
Methyl cyclopentane	6	0.041	0.025
Naphthalene	1	0.017	0.017
Phenol ethanone	4	0.059	0.033

Table 5.4-2 Summary of Phases 3 and 4 Nontarget VOC Field Blank Detections
Tenax Media ($\mu\text{g}/\text{sample}$)

Compound	No. of Detections	24-Hour Maximum	Mean
Alkanes	1	0.01	0.01
C3 benzene	2	0.02	0.02
Freons	5	0.20	0.11
Hexane	2	0.04	0.03
Ketones	4	0.05	0.03
Naphthalene	1	0.02	0.02
Phenol	1	0.01	0.01
Silanes	1	0.02	0.02

Table 5.4-3 Summary of Phases 1 and 2 Nontarget VOC Field Blank Detections in Tenax-and-charcoal Media ($\mu\text{g}/\text{sample}$)

Compound	No. of Detections	24-Hour Maximum	Mean
Acetaldehyde	1	0.013	0.013
Acetone	4	0.280	0.107
Aliphatic hydrocarbons	3	0.045	0.031
Alkanes	8	0.160	0.058
Alkenes	3	0.025	0.017
Benzaldehydes	2	0.042	0.029
Benzenes	5	0.130	0.043
C4 alkenyl cyclohexane	1	0.020	0.020
Chlorofluorocarbons	9	0.300	0.160
Chloromethane	1	0.037	0.037
Hexane	8	0.110	0.049
Methyl acetate	1	0.013	0.013
Methyl cyclopentane	2	0.020	0.015
Methyl formate	1	0.015	0.015
Naphthalene	1	0.054	0.054
Phenols	3	0.032	0.023
Phenyl ethanone	2	0.100	0.055
Trioxocane	2	0.019	0.018
Unknown silane	1	0.019	0.019

Table 5.4-4 Summary of Phases 3 and 4 Nontarget VOC Field Blank Detections in Tenax-and-charcoal Media ($\mu\text{g}/\text{sample}$)

Compound	No. of Detections	24-Hour Maximum	Mean
Acetate ester	1	0.04	0.04
Benzaldehyde	1	0.02	0.02
Cyclic alkene	1	0.02	0.02
Ethoxy methyl benzene	1	0.01	0.01
Freons	3	0.10	0.07
Hexane	1	0.03	0.03
Ketones	1	0.01	0.01
Limonene	1	0.02	0.02
Naphthalene	1	0.06	0.06
Oxygenated hydrocarbon	1	0.01	0.01
Phenol	1	0.07	0.07
Silanes	1	0.02	0.02

Table 5.4-5 Summary of Phases 1 and 2 Nontarget VOC Trip Blank Detections in Tenax Media ($\mu\text{g}/\text{sample}$)

Compound	No. of Detections	24-Hour Maximum	Mean
Alkanes	1	0.046	0.046
Alkenes	1	0.012	0.012
Freons	1	0.089	0.089
Methyl benzoate	1	0.014	0.014
Phenol	2	0.016	0.014
Trioxocane	1	0.015	0.015

Table 5.4-6 Summary of Phases 3 and 4 Nontarget VOC Trip Blank Detections in Tenax Media ($\mu\text{g}/\text{sample}$)

Compound	No. of Detections	24-Hour Maximum	Mean
Alkanes	10	0.07	0.03
Alkenes	4	0.08	0.04
Freons	1	0.10	0.10
Hexane	1	0.07	0.07
Ketones	1	0.09	0.09
Oxygenated hydrocarbon	2	0.01	0.01

Table 5.4-7 Summary of Phases 1 and 2 Nontarget VOC Trip Blank Detections in Tenax-and-charcoal Media ($\mu\text{g}/\text{sample}$)

Compound	No. of Detections	24-Hour Maximum	Mean
Alkenes	1	0.012	0.012
Benzaldehyde	1	0.011	0.011
Dimethoxy methane	1	0.035	0.035
Freons	2	0.400	0.218
Hexane	1	0.037	0.037
Methyl benzoate	1	0.016	0.016
Phenol	2	0.027	0.022
Unknown	1	0.023	0.023

Table 5.4-8 Summary of Phases 3 and 4 Nontarget VOC Trip Blank Detections in Tenax-and-charcoal Media ($\mu\text{g}/\text{sample}$)

Compound	No. of Detections	24-Hour Maximum	Mean
Limonene	1	0.01	0.01
Phenol	1	0.01	0.01

Numerous compounds were found to coelute during the analytical process, rendering positive identification virtually impossible. Coelution occurs with two compounds having similar molecular weights and retention times. The resulting chromatographic peaks of the two may occur at nearly the same time, causing only one peak to be discernable to the eye, when in actuality more than one chemical compound was present. The chemical groupings or specific compounds detected during the coelution phenomenon were the same compound types observed singularly at other times.

5.4.2 Nontarget SVOCs

Five nontarget SVOC field blanks and four nontarget SVOC trip blank were collected and analyzed during Phases 1 through 4 of the IRA-F program. These were examined for nontarget SVOCs that could be tentatively identified as members of a chemical group or as specific compounds. Detections seen for these blanks were laboratory contaminants (silanes), fatty acids and oxygen-containing hydrocarbons. The PUF is known to be a source of contamination from media breakdown (Hunt et al., 1986). Concentrations for these ranged from 30 to 100 μg per sample plug. The results of the field blank nontarget SVOCs analyses are presented in Tables 5.4-9 and 5.4-10, and the trip blank nontarget SVOCs results are presented in Table 5.4-11.

A total of 43 ambient samples were analyzed and examined for SVOC nontargets, 31 were from Phase 3 and 12 were from Phase 4. Thirteen of the unknowns detected could not be identified as belonging to any chemical group. The majority of detections were an apparent result of PUF decomposition (isocyanates, as identified by Hunt et al., 1986), laboratory contamination (phthalates), and background levels of polar and nonpolar organics from urban and rural air (ketones, hydrocarbons and polynuclear aromatics, as identified by Keller and Biddleman, et al., 1984). Maximum concentration levels ranged from 0.024 $\mu\text{g}/\text{m}^3$ to 0.714 $\mu\text{g}/\text{m}^3$ depending on the compound. All of the nontarget tentative identifications were normal for an urban/rural setting.

Table 5.4-9 Summary of Phases 1 and 2 Nontarget SVOC Field Blank Detections
(µg/sample)

Compound	No. of Detections	24-Hour Maximum	Mean
Acid	1	10	10
Aldehyde	1	8	8
Cyclohexene	8	200	115
Esters	18	20	11
Fatty acid ester	3	200	77
Isocyanates	1	8	8
Methyl hexanone	1	10	10
Nitrogen containing compounds	2	10	8
Substituted compounds	9	10	6
Toluene	4	40	18
Unknowns	48	100	30

Table 5.4-10 Summary of Phases 3 and 4 Nontarget SVOC Field Blank Detections
(µg/sample)

Compound	No. of Detections	24-Hour Maximum	Mean
Ethyl - hexanoic acid	4	30	14
Oxygenated aliphatic hydrocarbon	1	30	30
Silanes	11	40	21
Substituted fatty acid	2	100	85

Table 5.4-11 Summary of Phases 1 and 2 Nontarget SVOC Trip Blank Detections
(µg/sample)

Compound	No. of Detections	24-Hour Maximum	Mean
Acids	5	20	13
Cyclohexene	3	60	37
Esters	4	200	59
Fatty acid ester	2	100	60
Furans	1	7	7
Naphthalenes	2	10	8
Nitrogen containing compounds	1	9	9
Phenols	3	30	16
Poly nuclear aromatics	2	9	8
Substituted compounds	6	20	12
Unknowns	24	40	11

5.5 METHODOLOGY ISSUES

During the IRA-F program, MRI experienced a number of analytical method difficulties. Analytical errors can be placed in two categories. The first type, procedural error, was easily identified and solved, and was not a recurring problem. The second type, systematic method malfunction, was sometimes difficult to discover, but was more detrimental than the first type. The usual procedural errors, including instrument malfunction expired stock standards and sample breakage occurred, but within the expected sample loss range. The problems encountered and the impacts on the program are summarized below.

5.5.1 PMRMA Methods F-7 and CM02: Semivolatile Compound Analysis in Air Samples

Method F-7 was certified by PMRMA in 1988 to analyze for SVOCs in air, trapped on a PUF. In December 1989, Method F-7 quality controls were not within acceptable quality criteria for assessing method performance according to the CQAP. Those samples that were still analyzed despite lack of method control for F-7 were placed in the rejected database to be used for informational purposes only. The laboratory initiated re-certification in February 1990 and the re-certified method was accepted as CM02 by PMRMA in May 1990. Samples continued to be sent to the laboratory in hopes of a quick turnaround for re-certification. As a result, all SVOC samples for the period from January 11, 1990 to April 11, 1990 were not analyzed. Because there were many problems with re-certification, the laboratory developed a new SVOC analytical method called CM02, which included changes in procedures and detection limits. In addition, Parathion was not certified under the new method.

5.5.2 PMRMA Method E-7: Volatile Compound Analysis in Air Samples

Method E-7 was certified by PMRMA in 1988 and was designed to combine EPA Methods T0-1 and T0-2 for analysis of trapped VOCs. In March 1990, raw data were reviewed and found to contain occasional false negatives, base ion saturation due to possible matrix effects, truncated concentrations, and poor peak shape and reference spectra. In general, the method was not achieving all requirements specified in the certification, and therefore, was not providing data quality as required by the project and PMRMA programs. All situations were addressed and

corrective actions were put in place to resolve the method problems. Raw data were inspected after corrections were made and were found to be greatly improved.

There was an impact to the program in the form of method implementation. Saturation and truncation caused the generation of greater than the CRL (or GT) values, instead of more valid numbers within the certified range, to be used for assessing air concentrations. Estimates for GT values were calculated but were assumed to be lower than actual concentrations might have been. The GT concentrations for target analytes reported for method E-7 are conservative qualitative estimates.

5.5.3 PMRMA Method G-7: ICAP Metals Analysis in Air Samples

Method G-7 was certified by PMRMA in 1988. The method called for employing a glass fiber filter to trap TSP. The filter of choice was an EPM2000 manufactured by Whatman. In May 1989, a new filter was proposed for use because of the lack of heavy metals within the filter. Midwest Research Institute ordered the filters, prepared them for field sampling, and sent them to the site for immediate use. The laboratory did not analyze any of the new filters to confirm the specifications sent by Whatman. Instrument malfunction delayed analysis of the new filters until two months worth of sample filters had accumulated. When the first set of filters was analyzed, large amounts of arsenic, chromium, lead and zinc appeared in the blanks as well as the samples. Analysis of more blank filters confirmed that the wrong filter was ordered from Whatman. The laboratory quickly sent EPM2000 filters to the field and requested the return of the new filters. This situation resulted in the loss of eight weeks of metals data. The TSP data for that period were still valid because the contamination did not affect filter weight.

5.5.4 Method H-7: Organochlorine Pesticides Analysis in Air Samples

Method H-7 was certified by PMRMA in 1988. This method is related to Method F-7 in that the same PUF served as a sample for both methodologies. The PUF sample was extracted and the extract was split for analysis by both Method F-7 and Method H-7. The method exhibited some control problems starting in the summer of 1989. Over the next nine months the second

type of recurring errors appeared. Samples were lost due to laboratory mis-spiking, following improper method protocols, and lack of accuracy and precision. These were carefully tracked and any data affected by these errors were deleted from the database.

These problems have been identified to point out the potential problems in using the data and to provide a reference for addressing analytical problems in future RMA programs. The bulk of the data generated met PMRMA standards and can be used with confidence. Such sound data is the basis for this report.

6.0 COMPARISON OF RESULTS TO ACCEPTABLE AMBIENT CONCENTRATIONS

One of the goals of the IRA-F program was to compare the sample results to air quality standards or acceptable ambient concentrations (AACs), that have been derived from available technical literature. An AAC for a specific compound is the threshold for judging the acceptability of concentrations of that compound in the ambient air. Acceptable ambient concentrations can be developed from studies that determine the threshold concentrations below which no adverse effects were observed, or above which adverse effects were observed. Both acute (24-hour) and chronic AACs were developed for exposure limits and carcinogenic effects. The development of each group of AACs is provided in Section 6.2. As noted in Section 4, Basin F appeared to be a source for several toxic compounds, especially during the Phase 1 remedial activities. When IRA-F sampling began, the remedial activities had ceased, and the sampling results provide an estimate of air quality conditions following closure.

AACs have been developed for on-site workers and for off-site residents, including small children and adults, whose exposures to the measured concentrations are different, and whose sensitivity to those concentrations differ as well. In Section 6.1, the meteorological data and dispersion conditions are examined to provide "projections" of on-site conditions to off-site locations. The development of the AACs for all groups and the assumptions regarding exposure are described in Section 6.2. A comparison of the sample results and the appropriate AACs for on-site workers is provided in Section 6.3 and for off-site residents in Section 6.4. A summary of results is also provided. It must be emphasized that a series of conservative steps have been used to develop the AACs and to compare the results to potentially exposed populations. The conservative steps include evaluating the most sensitive population, the use of the 95th percentile of the dose response slope, the conservative assumptions regarding maximum exposure relating both to duration and location, a conservative averaging scheme for chronic exposures and conservative use of atmospheric dispersion models.

6.1 METEOROLOGICAL DATA AND DISPERSION EFFECTS

Because there was no sampling program off-post, it was necessary to use an atmospheric

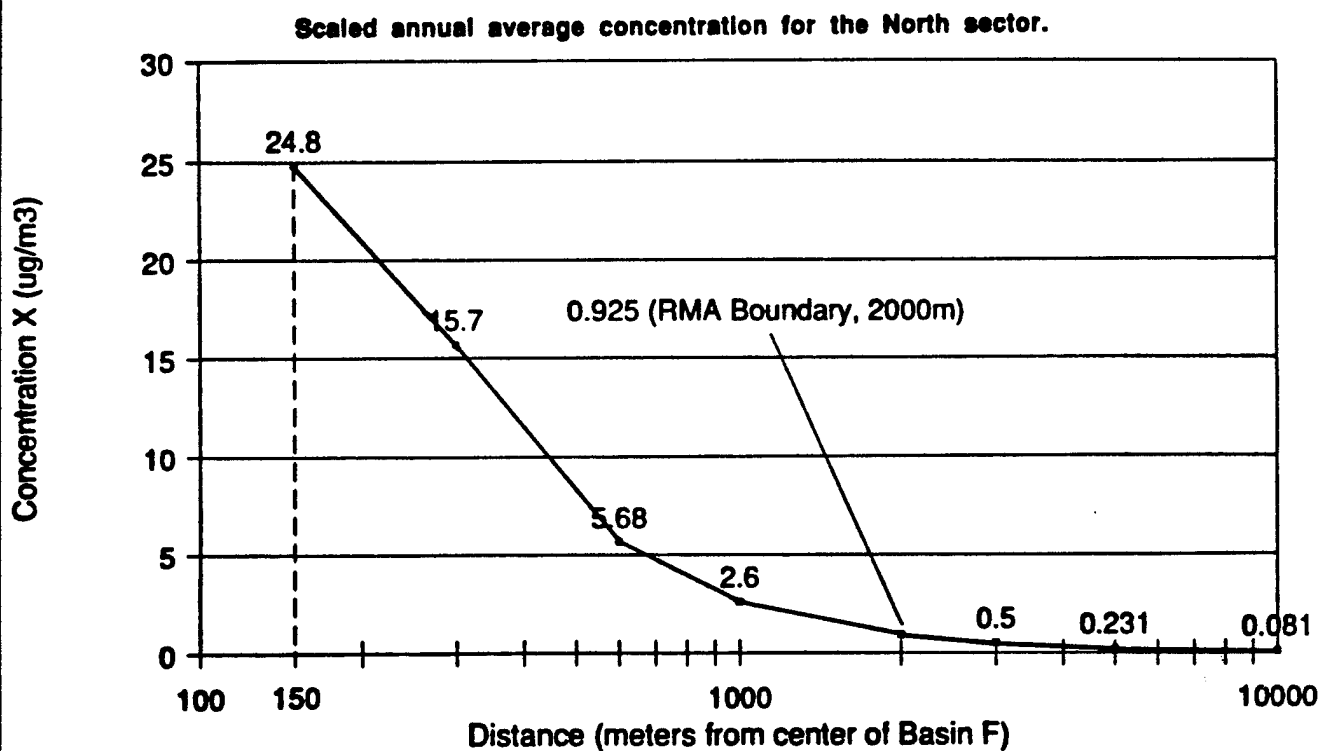
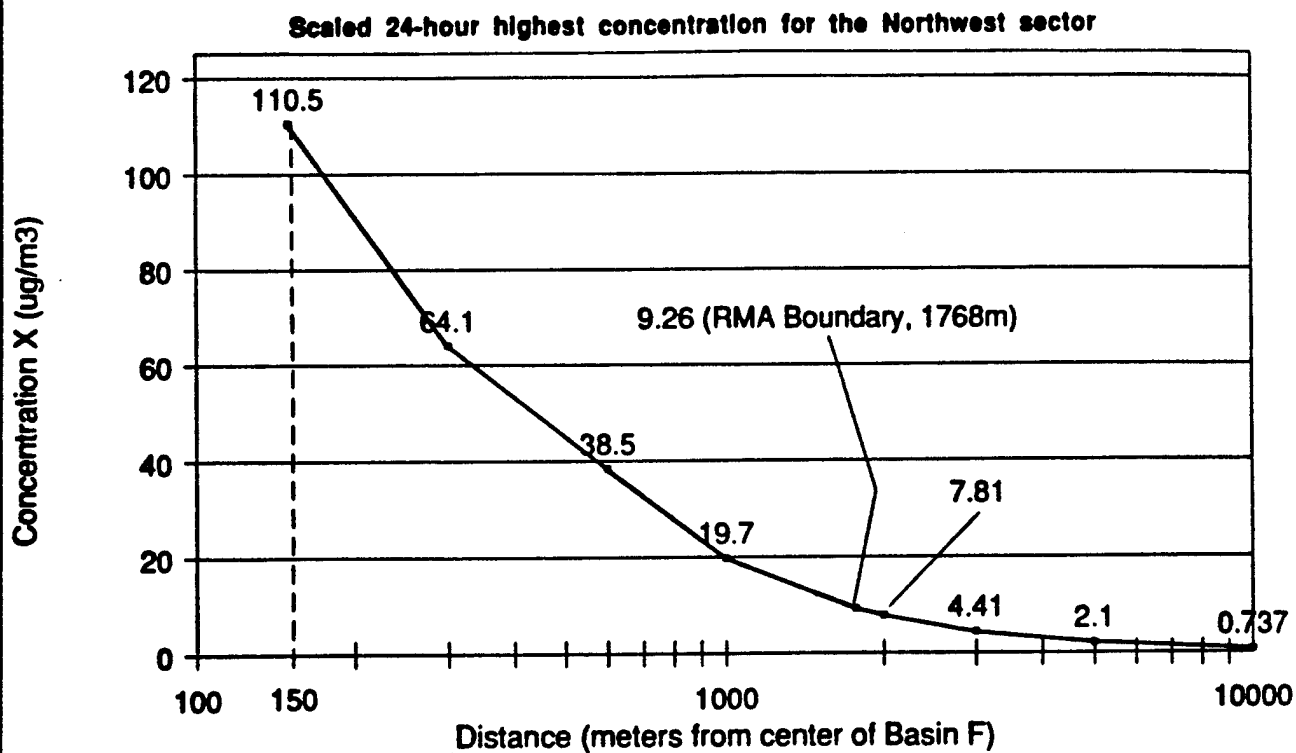
dispersion model to extend or extrapolate the on-site sample results to off-site locations. This extrapolation was necessary to compare AACs for off-site residents to their estimated exposure. This section describes the method used to perform that extrapolation and provides estimates of the mean and extreme concentrations for the target analytes for off-site locations.

Meteorological data were collected at RMA during the IRA-F monitoring period as a part of the CMP. A master database was developed from meteorological observations at four separate sites. The database includes wind direction, wind speed, atmospheric stability categories, temperature and other parameters for each hour of the monitoring period. The meteorological data were used to run the standard EPA-approved dispersion models, Industrial Source Complex Short-Term and Industrial Source Complex Long-Term (ISCST and ISCLT, respectively) to calculate the short-term and long-term impacts from a hypothetical Basin F source.

Basin F was characterized as an area source and divided into several smaller area sources for the purposes of modeling. A unit emissions rate of 1 g/sec was assumed for the entire basin for all periods during the modeling. Results of the model were used to generate dispersion, or relative concentration curves for each of 16 compass directions around Basin F. Both the worst case 24-hour and the annual average curves were generated. All 32 curves are presented in Appendix G, and the two directional curves with the highest potential concentrations at the RMA boundary are shown in Figure 6.1-1. Using the relative concentration curves shown in Figure 6.1-1, a measurement at any point along the curves can be used to estimate concentrations at any other point, under the assumption of a Basin F source. For example, measurements at monitoring locations along the Basin F perimeter can be used to estimate concentrations at the RMA boundary. The computed values, or dispersed concentrations, are presented and discussed in section 6.4.

6.2 DEVELOPMENT OF AACs

The AACs were developed from available technical literature and background information from previous studies in the Basin F area. The following sections describe the process of AAC



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7/91

Figure 6.1-1

**Directional Curves for 24-hour and Annual
Worst Case Concentrations
(October 1988 - September 1990)**

identification.

6.2.1 Available Literature

A substantial amount of technical literature is available to assess the impact on human health, from inhaling toxic compounds. Often, however, the results are not sufficiently complete to provide definitive assessments, and for many compounds, human health effects must be extrapolated from results of animal studies. There are three separate exposures that require evaluation. There are acute, or short-term, effects when a limited duration of time exposure to some chemicals causes adverse effects. There are also chronic effects, such as when exposures of an extended duration cause adverse health effects. A third consideration must be made for carcinogenic effects. The AACs were developed where applicable for each target analyte for each of the three exposure scenarios.

A toxicity assessment was carried out for the target analytes, with the expressed goal of developing AACs. Profiles for the contaminants of concern were collected, including summaries of relevant literature. These profiles are provided in Appendix H. The profiles are not meant to represent a complete analysis of all toxicological literature, but rather to provide an overview of the chemical effects. For more detail the reader is referred to the references cited in each of the profiles and to the Agency for Toxic Substances and Disease Registry.

6.2.2 Dose-Response Assessment

The dose-response assessment is intended to quantify the relationship between the magnitude of exposure to a chemical over a specified period and the occurrence of adverse health effects. This involved a detailed analysis of the relationships between the severity or frequency of adverse effects and the doses at which these effects occur for each chemical. Typically, this entails a review of the toxicological literature to identify chemical-specific dose-response estimates through oral, inhalation and dermal routes of exposure.

Dose-response assessments for chronic exposures have been compiled by EPA for a number of

chemicals in the form of reference doses (RfDs) for noncarcinogens and cancer potency factors (CPF) for carcinogens. Since the exposure pathway of concern associated with Basin F emissions is the inhalation pathway, inhalation reference doses were specifically used in the development of AACs. Dose-response data for other exposure routes (i.e., oral) were not considered in the development of AACs, consistent with EPA Risk Assessment Guidance for Superfund (EPA, 1989), since the data may not address specific organs and they do not address route specific absorption considerations. When inhalation RfDs were not available, the AACs could not be estimated.

Two exposure periods were evaluated for the development of AACs. These were the chronic, or long-term exposure, and the acute exposure (24-hours to two weeks). The period between two weeks and seven years is generally referred to as the sub-chronic exposure, and it has not been addressed here because there is a lack of information on most contaminants and also because the chronic AACs are likely to be more conservative and would be sufficiently protective of all receptors. Chronic dose-response values were obtained from the following information sources (in descending order of priority):

- EPA Integrated Risk Information System Database (IRIS)
- EPA Health Effects Assessment Summary Tables (HEAST)
- Agency for Toxic Substances and Disease Registry (ATSDR) Toxicological Profiles
- EPA Drinking Water Criteria Documents

Dose-response data for acute exposures have not been developed by EPA. Acute exposures were, therefore, evaluated based on threshold limit values (TLVs) established by the American Conference of Governmental Industrial Hygienists, (ACGIH, 1989) and permissible exposure limits (PELs) recommended by the Occupational Safety and Health Administration (OSHA), (29 CFR Part 1910). These standards, which are typically presented as a time-weighted average (TWA) for an 8-hour working day, have been established to protect the health of workers against the effects of adverse occupational exposures on a daily basis. The TLVs are typically set at a

level to protect workers for acute health effects such as irritation of the eyes and throat.

While it is recognized that the TLVs and PELs are not an ideal standard against which exposures of the general public should be evaluated, they can be used as a basis for extrapolating health risks to the general population. This extrapolation allows for the quantification of acute health risks that would not otherwise be possible. It should be noted that the TLVs and PELs have been used in the development of AACs by the states of New York, Massachusetts, and Washington (NYSDEC, 1986; MDEQE, 1985; WDOE, 1988).

The dose-response estimates used as the basis for developing AACs for acute and chronic inhalation exposures are presented in separate tables. In these tables, the list of compounds includes the target analytes and nontarget compounds for which applicable dose-responses, cancer potency factors, or acute dose-response estimates were available. Table 6.2-1 provides the PELs and TLVs used as a basis for acute dose-response evaluations. For acute values both the ACGIH and OSHA values are shown and the more conservative (minimum TWA) of the two standards is identified. Table 6.2-2 summarizes the chronic dose-response estimates for noncarcinogenic effects. A subjective uncertainty factor is also provided to indicate the relative confidence of the RfD in causing the critical effects.

In developing dose-response values for noncarcinogenic effects the goal was to identify the highest no-observed-adverse-effect-level or NOAEL (i.e., the upper limit of the tolerance range) or the lowest-observed-adverse-effect-level, or LOAEL, from well designed human or animal studies. The confidence level or adequacy of the database used to derive the RfD is qualified with a rating of low, medium or high. This confidence is based on the uncertainties of extending results from the referenced human or animal study to the general population.

Chronic dose-response estimates for carcinogens are presented in Table 6.2-3 along with the designated EPA weight of evidence category that qualitatively defines the degree of certainty in the human carcinogenic potential of each chemical. This table is summarized as follows:

Table 6.2-1 Acute Dose-Response Estimates for Contaminants of Concern

Targent Compounds	TWA (OSHA) (mg/m ³)	TWA (ACGIH) (mg/m ³)	MINIMUM TWA (mg/m ³)
VOCs			
Benzene	3.20E+01	3.20E+01	3.20E+01
Bicycloheptadiene	NA	NA	NA
Carbon tetrachloride	1.26E+01	3.10E+01	1.26E+01
Chlorobenzene	3.50E+02	4.60E+01	4.60E+01
Chloroform	9.78E+00	4.90E+01	9.78E+01
Dibromochloropropane	NA	NA	NA
1,1-dichloroethane	4.00E+02	8.10E+02	4.00E+02
1,2-dichloroethane	4.00E+00	4.00E+01	4.00E+00
t-1,2-dichloroethylene ¹	7.90E+02	7.93E+02	7.90E+02
Dicyclopentadiene	3.00E+01	2.70E+01	2.70E+01
Dimethyl disulfide	NA	NA	NA
Ethylbenzene	4.35E+02	4.34E+02	4.34E+02
Hexachlorobutadiene	2.40E-01	2.10E-01	2.10E-01
n-Hexane	1.80E+02	1.76E+02	1.76E+02
Methylene Chloride	1.72E+03	1.74E+02	1.74E+02
Methyl isobutyl ketone	2.05E+02	2.05E+02	2.05E+02
n-Nitrosodimethylamine	NA	NA	NA
Tetrachloroethylene	1.70E+02	3.39E+02	1.70E+02
Toluene	3.75E+02	3.77E+02	3.75E+02
1,1,1-Trichloroethane	1.90E+03	1.91E+03	1.90E+03
1,1,2-Trichloroethane	4.50E+01	5.50E+01	4.50E+01
Trichloroethylene	2.70E+02	2.69E+02	2.69E+02
o-Xylene ²	4.35E+02	4.34E+02	4.34E+02
m,p-Xylene ²	4.35E+02	4.34E+02	4.34E+02
SVOCs			
Aldrin	2.50E-01	2.50E-01	2.50E-01
Atrazine	5.00E+00	5.00E+00	5.00E+00
Chlordane	5.00E-01	5.00E-01	5.00E-01
P-chlorophenylmethyl sulfoxide	NA	NA	NA
P-chlorophenylmethyl sulfone	NA	NA	NA
Dieldrin	2.50E-01	2.50E-01	2.50E-01
ppDDE	NA	NA	NA
ppDDT	NA	100E+00	1.00E+00
Endrin	1.00E-01	1.00E-01	1.00E-01
Isodrin	NA	NA	NA
Malathion (Total Dust)	1.00E+01	1.00E+01	1.00E+01
Parathion	1.00E-01	1.00E-01	1.00E-01
Supona	NA	NA	NA
METALS			
Arsenic ³	5.00E-01	2.00E-01	2.00E-01
Cadmium (Dust)	2.00E-01	1.00E-02	1.00E-02
Chromium (VI)	1.00E+00	5.00E-02	5.00E-02
Copper (Dust and Mists)	1.00E+00	1.00E+00	1.00E+00
Lead	NA	1.50E-01	1.50E-01
Mercury ⁵	1.00E-01	1.00E-01	1.00E-01
Zinc ⁴	1.00E+01	1.00E+01	1.00E+01

- Footnotes:
- 1 TWA reported as 1,2-Dichloroethylene.
 - 2 TWA reported as o,m,p-isomers.
 - 3 OSHA arsenic TWA reported as organic compounds.
 - 4 Zinc TWA as zinc oxide (dust).
 - 5 Mercury TWA for mercury aryl and inorganic compounds
 - 6 NA - Not Applicable
 - 7 ppDDE - p,p'Dichlorodiphenylethane
 - 8 ppDDT - p,p'Dichlorodiphenyltrichloroethane

Table 6.2-2 Chronic Dose-Response Estimates for Noncarcinogenic Chemicals

Chemical	Chronic RfD (mg/kg/day)	Exposure Route	Source	Critical Effects	Uncertainty Factor
VOCs					
Chlorobenzene	5.00E-03	Inhalation	HEAST	Liver and Kidney toxicity.	10000
1,4-dichlorobenzene	2.00E-01	Inhalation	HEAST	Liver and kidney toxicity	100
1,1-dichloroethane	1.00E-01	Inhalation	HEAST	Kidney toxicity.	1000
Dicyclopentadiene	6.00E-05	Inhalation	HEAST	Kidney toxicity.	10000
Ethylbenzene	2.86E-01	Inhalation	HEAST	Hepatotoxicity and neurotoxicity	300
n-Hexane	5.71E-02	Inhalation	IRIS	Neurotoxicity.	300
Methylene chloride	8.60E-01	Inhalation	HEAST	Liver toxicity.	100
Methyl isobutyl ketone	2.00E-02	Inhalation	HEAST	Liver and kidney toxicity.	1000
Toluene	5.70E-01	Inhalation	HEAST	CNS effects and hematological parameters.	100
1,1,1-trichloroethane	3.00E-01	Inhalation	HEAST	Liver toxicity.	1000
o-Xylene	2.00E-01	Inhalation	HEAST	Hyperactivity and increased body weight.	5000
m,p-Xylene (mixed xylenes)	8.60E-02	Inhalation	HEAST	CNS effects, hyperactivity and increased body weight.	100
METALS					
Chromium (VI)	5.70E-07	Inhalation	HEAST	Nasal mucosa atrophy.	300
Mercury	8.60E-05	Inhalation	HEAST	Neurotoxicity.	30

Source: HEAST - Health Effects Assessments Summary Tables
IRIS - Integrated Risk Information System

Table 6.2-3 Dose-Response Estimates for Carcinogenic Chemicals

Chemical	Cancer Potency Estimate ¹ (mg/kg-day)	Exposure Route	Risk Specific Dose (RSD) ² (gm/kg-day)	Source	Carcinogenic Classification
VOCs					
Benzene	2.92E-02	Inhalation	3.42E-05	IRIS	A
Carbon tetrachloride	1.30E-01	Inhalation	7.69E-06	HEAST	B2
Chloroform	8.10E-02	Inhalation	1.23E-05	IRIS	B2
Dibromochloropropane	2.20E+01	Inhalation	4.55E-08	HEAST	B2
1,2-dichloroethane	9.10E-02	Inhalation	1.10E-05	IRIS	B2
Methylene chloride	1.60E-03	Inhalation	6.25E-04	IRIS	B2
n-Nitrosodimethylamine	5.10E+01	Inhalation	1.96E-08	IRIS	B2
Tetrachloroethylene	1.82E-03	Inhalation	5.49E-04	HEAST	B2
1,1,2-trichloroethane	5.70E-02	Inhalation	1.75E-05	IRIS	C
Trichloroethylene	5.95E-03	Inhalation	1.68E-04	EPA	B2
SVOCs					
Aldrin	1.70E+01	Inhalation	5.88E-08	HEAST	B2
Chlordane	1.30E+00	Inhalation	7.69E-07	HEAST	B2
ppDDE	3.40E-01	Inhalation	2.94E-06	IRIS	B2
ppDDT	3.40E-01	Inhalation	2.94E-06	IRIS	B2
Dieldrin	1.60E+01	Inhalation	6.25E-08	IRIS	B2
METALS					
Arsenic	1.50E+01	Inhalation	6.67E-08	EPA	A
Cadmium	6.10E+00	Inhalation	1.64E-07	IRIS	B1
Chromium	4.10E+01	Inhalation	2.44E-08	IRIS	A

Sources: EPA - Adjusted to reflect an administered dose.
HEAST - Health Effects Assessments Summary Tables.
IRIS - Integrated Risk Information System.

Footnotes: 1 = Values are only presented for those chemicals which have available Inhalation dose-response data.
2 = The risk specific dose (RSD) was computed from the CPF and an acceptable risk level (ARL) of 1E-06
3 = Inhalation dose-response data for DDT was substituted for DDE due to lack of available information.
ppDDE = p,p'-dichlorodiphenylethane
ppDDT = p,p'-dichlorodiphenyltrichloroethane

- Group A - Human Carcinogen
- Group B - Probable Human Carcinogen
- Group B1 - At least limited evidence of carcinogenicity to humans.
- Group B2 - A combination of sufficient evidence in animals and inadequate evidence in humans.
- Group C - Possible Human Carcinogen (limited evidence of carcinogenicity in animals and the absence of human data).
- Group D - Not classifiable as to human carcinogenicity.
- Group E - Evidence of noncarcinogenicity in humans (no evidence in at least two adequate animal tests in different species or in both epidemiological and animal studies).

These dose-response estimates were used to develop AACs appropriate to the exposure scenario and to the target receptors discussed in the following section.

6.2.3 Chemical Specific Data

The chemicals for which AACs were developed were identified from the list of target and nontarget compounds for the IRA-F air monitoring program, as summarized in Section 4. Table 6.2-4 lists these target and nontarget compounds for which AACs were developed. One nontarget compound was also evaluated since appropriate dose-response data were available. AACs were not developed for target or nontarget compounds lacking dose-response data.

6.2.4 Receptors

AACs were developed for three categories of receptors; on-site workers and off-site residents including small children and adults. On-site workers were divided into acute and chronic exposure groups. For acute exposures, workers were presumed to be exposed to the maximum levels detected at any one location. For chronic exposures to on-site workers, it was appropriate to use the group which was expected to receive the maximum exposure. At the time of the

Table 6.2-4

List of Target Compounds for Which AACs Were Developed

Target Compound	Acute	Chronic	Cancer Potency Factor
Aldrin	X		X
Arsenic	X		X
Atrazine	X		X
Benzene	X		X
Cadmium	X		X
Carbon tetrachloride	X		X
Chlordane	X		X
Chlorobenzene	X	X	
Chloroform	X		X
Chromium (VI)	X	X	X
Copper	X		X
ppDDT	X		X
Dibromochloropropane			X
1,1-dichloroethane	X	X	
1,2-dichloroethane	X		X
Trans-1,2-dichloroethylene	X		
Dicyclopentadiene	X	X	
Dieldrin	X		X
Endrin	X		
Ethylbenzene	X		
n-Hexane*	X	X	
Lead	X		
Malathion	X		
Mercury	X	X	
Methyl isobutyl ketone	X	X	
Methylene chloride	X	X	X
n-Nitrosodimethylamine			X
Parathion	X		
Tetrachloroethylene	X		X
Toluene	X	X	
1,1,1-trichloroethane	X	X	
1,1,2-trichloroethane	X		X
Trichloroethylene	X		X
o-Xylene	X	X	
m,p-Xylene	X	X	
Zinc	X		

* = Not a target compound

X = AAC developed for this compound

ppDDT = p,p'Dichlorodiphenyltrichloroethane

completion of the IRA-F program, this was the group of workers at the north boundary treatment system. Workers were assumed to be exposed for a period of 7 years for chronic exposure. Off-site residents were assumed to be at any location at the RMA boundary. Acute exposures were based on the 24-hour exposure, and chronic exposures were based on a 75-year lifetime, with a seven year exposure.

6.2.4.1 On-Site Worker

The chronic AAC for an on-site worker was computed in a manner consistent with the pathway model for inhalation exposure in the EPA Risk Assessment Guidance for Superfund (EPA, 1989). This pathway equation was

$$AAC_{\text{chronic}} = (BW * AT * AD) / (IR * ET * EF * ED)$$

where:

AAC _{chronic} = Acceptable Ambient Concentration	(mg/m ³)
IR = Inhalation Rate	(1.25 m ³ /hour, EPA, 1989)
ET = Exposure Time	(8 hours/day)
EF = Exposure Frequency	(250 days/year)
ED = Exposure Duration	(7 years)
BW = Body Weight	(70 kg)
AT = Averaging Time (days in period)	(2,555 days for noncarcinogens) (27,375 days for carcinogens)
AD = Allowable Dose	(chemical specific, mg/(kg-day))

With the exception of ED, the parameters for the chronic AAC development were obtained from EPA Risk Assessment Guidance for Superfund (EPA, 1989). The assumed exposure frequency is based on five working days per week, 50 weeks per year. Compound-specific chronic AACs for the on-site worker are summarized in Table 6.2-5.

The acute AACs for the on-site worker are summarized in Table 6.2-6. The acute AACs for the on-site worker were assumed to be the more conservative of the OSHA or ACGIH values as

Table 6.2-5 Chronic AACs for RMA On-site Workers

Chemical	AAC Noncarcinogens (mg/m ³)	AAC Carcinogens (mg/m ³)	Minimum AAC (mg/m ³)
VOCs			
Benzene		3.75E-03	3.75E-03
Carbon tetrachloride		8.42E-04	8.42E-04
Chlorobenzene	5.11E-02		5.11E-02
Chloroform		1.35E-03	1.35E-03
Dibromochloropropane		4.98E-06	4.98E-06
1,2-dichloroethane		1.20E-03	1.20E-03
Ethylbenzene	2.92E+00		2.92E+00
Methylene chloride	8.79E+00	6.84E-02	6.84E-02
Methyl isobutyl ketone	2.04E-01		2.04E-01
Tetrachloroethylene		6.02E-02	6.02E-02
Toluene	5.83E+00		5.83E+00
1,1,1-Trichloroethane	3.07E+00		3.07E+00
Trichloroethylene		1.84E-02	1.84E-02
o-Xylene	2.04E+00		2.04E+00
m,p-Xylene (mixed)	8.79E-01		8.79E-01
SVOCs			
Aldrin		6.44E-06	6.44E-06
Chlordane		8.42E-05	8.42E-05
Dieldrin		6.84E-06	6.84E-06
ppDDT		3.22E-04	3.22E-04
METALS			
Arsenic		7.30E-06	7.30E-06
Cadmium		1.80E-05	1.80E-05
Chromium (VI)	5.83E-06	2.67E-06	2.67E-06
Mercury	8.79E-04		8.79E-04

ppDDT = p,p'-dichlorodiphenyltrichloroethane

Table 6.2-6

Acute AACs for On-site Workers and Off-site Residents

Targent Compounds	Worker	Residential
	Onsite AAC (mg/m ³)	Offsite AAC (mg/m ³)
VOCs		
Benzene	3.20E+01	1.07E+00
Carbon tetrachloride	1.26E+01	4.20E-01
Chlorobenzene	4.60E+01	1.53E+00
Chloroform	9.78E+00	3.26E-01
1,1-dichloroethane	4.00E+02	1.33E+01
1,2-dichloroethane	4.00E+00	1.33E-01
t-1,2-dichloroethylene ¹	7.90E+02	2.63E+01
Dicyclopentadiene	2.70E+01	9.00E-01
Ethylbenzene	4.34E+02	1.45E+01
Methylene chloride	1.74E+02	5.80E+00
Methyl isobutyl ketone	2.05E+02	6.83E+00
Tetrachloroethylene	1.70E+02	5.67E+00
Toluene	3.75E+02	1.25E+01
1,1,1-trichloroethane	1.90E+03	6.33E+01
1,1,2-trichloroethane	4.50E+01	1.50E+00
Trichloroethylene	2.69E+02	8.97E+00
o-Xylene ²	4.34E+02	1.45E+01
m,p,-Xylene ²	4.34E+02	1.45E+01
SVOCs		
Aldrin	2.50E-01	8.33E-03
Atrazine	5.00E+00	1.67E-01
Chlordane	5.00E-01	1.67E-02
Dieldrin	2.50E-01	8.33E-03
ppDDT ⁶	1.00E+00	3.33E-02
Endrin	1.00E-01	3.33E-03
Malathion (Total Dust)	1.00E+01	3.33E-01
Parathion	1.00E-01	3.33E-03
METALS		
Arsenic ³	2.00E-01	6.67E-03
Cadmium (Dust)	1.00E-02	3.33E-04
Chromium (VI)	5.00E-02	1.67E-03
Copper (Dust and Mists)	1.00E+00	3.33E-02
Lead	1.50E-01	5.00E-03
Mercury ⁵	1.00E-01	3.33E-03
Zinc ⁴	1.00E+01	3.33E-01

- Footnotes:
- 1 TWA reported as 1,2-Dichloroethylene
 - 2 TWA reported as o,m,p-isomers
 - 3 OSHA arsenic TWA reported as organic compounds
 - 4 Zinc TWA as zinc oxide (dust)
 - 5 Mercury TWA for mercury aryl and inorganic compounds
 - 6 p,p'-dichlorodiphenyltrichloroethane

shown in the table.

6.2.4.2 Off-site Residents

In order to protect the most sensitive age groups, AACs were developed for "small children" using children ages 0 to 7 years of age. A separate set of AACs was developed for adults only. The chronic AACs for residential exposure were calculated in a two-step process. In the first step, an average daily AAC was calculated for each of seven age groups comprising an individual's lifetime (0-3 years, 3-6, 6-9, 9-12, 12-15, 15-18, 18-75 years) as shown below:

$$AAC_i = (BW_i * AD) / (IR_i * ET * EF * ED_i)$$

AAC_i = Normalized Acceptable Ambient Concentration

for age group i

(mg/m³-day)

IR_i = Inhalation Rate

(0.6667 m³/hour (children))

(0.8 m³/hour (adults))

ET = Exposure Time

(24-hours/day)

EF = Exposure Frequency

(350 days/year)

ED_i = Exposure Duration

(years, specific to age group)

BW_i = Body Weight

(kg, specific to age group)

AD = Allowable dose

(chemical specific, mg/(kg/day))

In the second step, a final chronic AAC was computed as a function of the average daily AAC and the number of days in the total exposure period:

$$AAC_{\text{chronic}} = AT / (1/AAC_1 + 1/AAC_2 + \dots + 1/AAC_7)$$

where AT is averaging time, or the number of days in the exposure period. In effect, the chronic AAC will most closely approximate the AAC for the most sensitive life stage. Typically, this will be the youngest age group since it is these individuals who receive a higher contaminant

dose per unit of body weight and who may be at greater risk of experiencing adverse effects. Chronic AACs for the off-site residents (small children and adults) are summarized for each compound in Table 6.2-7, based both on the carcinogenic and noncarcinogenic effects.

Acute AACs for off-site residents were computed from the 8-hour OSHA or ACGIH PEL/TLV values as:

$$AAC_{acute} = (PEL \text{ or } TLV)/30$$

The factor of 30 represents two adjustments, including a factor of 3 to adjust from an 8-hour exposure to a 24-hour exposure, and a factor of 10 to address sensitive populations. Acute AACs for protection of off-site residents are shown in Table 6.2-6.

6.3 ASSESSMENT OF AACs FOR ON-SITE WORKERS

The AACs developed for on-site workers have been compared to the sample values observed during the IRA-F program. If Basin F was acting as a source for any of the measured compounds, the maximum concentration (exclusive of within Basin F) would have been observed at the IRA-F sampling locations around the Basin F perimeter. A comparison of these values to the AACs is a very conservative means of addressing impacts to on-site workers.

The basic approach used here is essentially a "screening level" analysis or comparison. If this analysis indicated that there was no exceedance of an AAC, then it could be assumed that there were no exposures of concern. If the screening level analysis shows that ambient levels were above the AAC, then a more detailed analysis of the sample results and the nature of the compound, its source or exposure were required. The screening analysis and any comparisons requiring further elaboration are presented below.

6.3.1 Acute Exposures

Acute exposures were assumed to occur on the basis of a 24-hour period. On-site workers were

Table 6.2-7 Chronic AACs for Off-site Residents

Chemical	AAC Noncarcinogens Small Children (mg/m ³)	AAC Carcinogens Small Children (mg/m ³)	Minimum AAC Small Children (mg/m ³)	AAC Noncarcinogens Adults (mg/m ³)	AAC Carcinogens Adults (mg/m ³)	Minimum AAC Adults (mg/m ³)
VOCs						
Benzene		3.59E-04	3.59E-04		1.34E-03	1.34E-03
Carbon tetrachloride		8.06E-05	8.06E-05		3.01E-04	3.01E-04
Chlorobenzene	4.89E-03		4.89E-03	1.83E-02		1.83E-02
Chloroform		1.29E-04	1.29E-04		4.83E-04	4.83E-04
Dibromochloropropane		4.76E-07	4.76E-07		1.78E-06	1.78E-06
1,2-dichloroethane		1.15E-04	1.15E-04		4.03E-04	4.03E-04
Ethylbenzene	2.80E-01		2.80E-01	1.04E-00		1.04E-00
Methylene chloride	8.41E-01	6.55E-03	6.55E-03	3.14E+00	2.44E-02	2.44E-02
Methyl isobutyl ketone	1.96E-02		1.96E-02	7.30E-02		7.30E-02
Tetrachloroethylene		5.76E-03	5.76E-03	2.15E-02		2.15E-02
Toluene	5.57E-01		5.57E-01	2.08E+00		2.15E+00
1,1,1-trichloroethane	2.93E-01		2.93E-01	1.10E+00		1.10E+00
Trichloroethylene		1.76E-03	1.76E-03		6.57E-03	6.57E-03
o-Xylene	1.96E-01		1.96E-01	7.30E-01		7.30E-01
m,p-Xylene (mixed)	8.41E-02		8.41E-02	3.14E-01		3.14E-01
SVOCs						
Aldrin		6.16E-07	6.16E-07		2.30E-06	2.30E-06
Chlordane		8.06E-06	8.06E-06		3.01E-05	3.01E-05
Dieldrin		6.55E-07	6.55E-07		2.44E-06	2.44E-06
ppDDT		3.08E-05	3.08E-05		1.15E-04	1.15E-04
METALS						
Arsenic		6.99E-07	6.99E-07		2.61E-06	2.61E-06
Cadmium		1.72E-06	1.72E-06		6.41E-06	6.41E-06
Chromium (VI)	5.57E-07	2.56E-07	2.56E-07	2.08E-06	9.54E-07	9.54E-07
Mercury	8.41E-05		8.41E-05	3.14E-04		3.14E-04
ppDDT=p,p'Dichlorodiphenyltrichloroethane						

generally assumed to be exposed for the 8-hour duration of their work day; however, samples were collected over a 24-hour period. The data used to generate the acute AACs, however, were based on an 8-hour working period as well. For this reason, comparison of the AACs based on an 8-hour exposure is a reasonable approach to addressing impacts.

A comparison of the derived AACs to the maximum observed 24-hour concentration for selected target analytes is presented in Table 6.3-1. Target analytes for which no acute AACs were available are not included in the table. A quick scan of the comparison indicates that all sample maxima were many orders of magnitude below the AACs. It can readily be concluded that there was no problem with acute, or short-term exposure to on-site workers.

6.3.2 Chronic Exposures

Chronic exposures were assumed to occur over a seven year exposure while working at the nearest site with routine exposure (the North Boundary Treatment System) at RMA. The sample results that were used for comparison were computed as an average of a 12-month sampling program (Phase 4). Because of the limited sampling period, these results may not be representative for long-term conditions. If the potential source were handled or treated in any way, the impacts from the source would change as well. Presumably, all remediation efforts would lead to a long-term reduction in emissions, and therefore, an assessment of chronic impacts using the IRA-F data would provide a conservative comparison to AACs developed from chronic exposures.

The comparison of AACs for on-site workers for chronic exposures to the target compounds is presented in Table 6.3-2. For all of the analytes, the IRA-F value was below the AAC, indicating that exposures were below the threshold of concern. This result must be viewed under the array of conservative assumptions used to compare AACs to exposures, giving further credence to the results.

Table 6.3-1 Comparison of AACs for Acute Exposure of On-site Workers to Estimated 24-hour Maximum Concentration ($\mu\text{g}/\text{m}^3$)

Chemical	AAC	Sampled Value
VOCs		
1,1,1-trichloroethane	1,900,000	4.6
1,1,2-trichloroethane	45,000	0.06
1,1-dichloroethane	400,000	0.05
1,2-dichloroethane	400,000	0.25
Benzene	32,000	3.53
Carbon tetrachloride	12,600	1.64
Chlorobenzene	46,000	0.11
Chloroform	9,780	2.23
Dicyclopentadiene	27,000	ND
Ethylbenzene	434,000	3.99
Methylene chloride	174,000	6.77
Methyl isobutyl ketone	205,000	1.13
Tetrachloroethylene	170,000	6.34
Trans-1,2-dichloroethylene	790,000	0.06
Toluene	375,000	10.9
Trichloroethylene	269,000	1.52
o-Xylene	434,000	0.86
m- and p-Xylene	434,000	7.09
Total xylenes	434,000	9.5
SVOCs		
Aldrin	250	0.03
Chlordane	500	0.0023
Dieldrin	250	0.0720
Endrin	100	0.0067
ppDDT	1,000	0.0041
METALS		
Arsenic	200	0.0072
Cadmium	10	0.0042
Chromium	50	0.015
Copper	1,000	0.26
Lead	150	0.0502
Mercury	100	2.70
Zinc	10,000	0.073

ppDDT = p,p'Dichlorodiphenyltrichloroethane

NA = Not Applicable

ND = Not Detected

Table 6.3-2 Comparison of AACs for Chronic Exposure to On-site Workers to Projected Highest Average Concentration (ug/m³) at North Boundary Well Monitoring Site

	AAC	On-Site Value
VOCs		
Benzene	3.75	0.18
Carbon tetrachloride	0.842	0.074
Chlorobenzene	51.1	0.0027
Chloroform	1.35	0.004
Dibromochloropropane	0.0050	0.0027
1,2-dichloroethane	1.2	0.008
Ethylbenzene	2,920.0	0.076
Methylene chloride	68.4	0.071
Methyl isobutyl ketone	204.0	0.012
Tetrachloroethylene	60.2	0.10
Toluene	5,830.0	0.52
1,1,1-trichloroethane	3,070.0	0.19
Trichloroethylene	18.4	0.009
o-Xylene	2,040.0	0.10
m- and p-Xylene	879.0	0.22
SVOCs		
Aldrin	0.00644	0.00007
Chlordane	0.0842	0.00004
Dieldrin	0.00684	0.00047
ppDDT	0.322	0.00003
METALS		
Arsenic	0.0073	0.00007
Cadmium	0.018	0.00007
Chromium	0.00267	0.00036
Mercury	0.879	0.060

ppDDT = Dichlorodiphenyltrichloroethane

6.4 ASSESSMENT OF AACs FOR NEARBY RESIDENTS

In a manner similar to that for on-site workers, the AACs can be compared to concentrations expected for nearby off-site residents. Since no data were collected off site, the actual concentrations must be estimated by using a dispersion algorithm and by making an assumption, not always valid, that Basin F was the source of the target analyte. The comparison between the dispersed concentration and the AACs provided a screening mechanism which was used to examine crucial analytes in more detail.

The off-site concentrations were calculated by using the average and maximum data for each site and by adjusting the results based on the relative concentration curves shown in Figure 6.1-1. The nearest off-site resident was assumed to be at the boundary of RMA in the direction that had the maximum projected impact. If the calculated concentration at the RMA boundary was above the AAC, the data and potential sources for that analyte were analyzed in more detail.

This type of analysis was appropriate only for compounds that had a clear source at Basin F. For compounds that had an urban area source (such as benzene, toluene, and xylenes), the concentration to which off-site residents were exposed may actually have been greater than the concentration sampled on RMA. The source of the exposure, however, was not from Basin F or RMA in general, and there are no RMA remediation activities which can be undertaken to address those exposures.

6.4.1 Acute AACs

As noted in Section 6.3, the acute AACs for nearby residents were developed from the available data for industrial workers, with conservative adjustments for the length of exposure and for the assumed sensitivity of off-site populations. The acute AACs are provided in Table 6.4-1 along with the maximum sampled concentration for the IRA-F program. It would normally be appropriate to provide an additional adjustment to the sampled concentrations, based on the dispersion algorithm; but this is not necessary because, as with the on-site workers, the sampled levels were many orders of magnitude below the acute AACs. The comparison points out that

Table 6.4-1 Comparison of AACs for Acute Exposure to Off-site Residents to Estimated 24-hour Maximum Concentration (ug/m³)

	AAC	Sampled Value
VOCs		
1,1,1-Trichloroethane	63,300	4.6
1,1,2-Trichloroethane	1,500	0.06
1,1-Dichloroethane	1,330	0.05
1,2-dichloroethane	1,330	0.25
Benzene	1,070	3.53
Carbon tetrachloride	420	1.64
Chlorobenzene	1,530	0.11
Chloroform	326	2.23
Dicyclopentadiene	900	ND
Ethylbenzene	1,450	3.99
Methylene chloride	5,800	6.77
Methyl isobutyl ketone	6,830	1.13
Tetrachloroethylene	5,670	6.34
Trans-1,2-dichloroethylene	NA	0.06
Toluene	12,500	10.9
Trichloroethylene	8,970	1.52
o-Xylene	14,500	3.19
m- and p-Xylene	14,500	7.09
Total xylenes	14,500	9.5
SVOCs		
Aldrin	8.33	0.03
Chlordane	16.7	0.0023
Dieldrin	8.33	0.00720
Endrin	3.33	0.0067
Isodrin	NA	0.0106
ppDDT	NA	0.0041
ppDDE	NA	0.0006
METALS		
Arsenic	6.67	0.0072
Cadmium	0.33	0.0042
Chromium	1.67	0.015
Copper	33.3	0.26
Lead	5.0	0.0502
Mercury	3.33	2.70
Zinc	333.0	0.073

ppDDE = Dichlorodiphenylethane
 ppDDT = Dichlorodiphenyltrichloroethane
 CPMSO = P-Chlorophenylmethyl sulfoxide
 CPMSO₂ = P-Chlorophenylmethyl sulfone
 NA = Not Applicable
 ND = Not Detected

there were likely to be no acute risks to the off-site residents associated with the short-term sampled IRA-F concentrations.

6.4.2 Chronic AACs

Table 6.4-2 provides a comparison of the chronic AACs for off-site residents to both the sampled on-site maximum average concentration and to a "dispersed value" that was adjusted by a factor of 0.09 to account for the average dispersion shown in Figure 6.1-1. For most target analytes, the dispersed value was less than the AAC, and therefore these analytes were "screened" from further analysis. The dispersed Basin F values for dibromochloropropane (DBCP), Dieldrin, and chromium were above the AACs for small children and the value for DBCP was above the AACs for adults. Each of these analytes is discussed in detail below.

DBCP average concentrations were above the chronic AAC. It is important to note, however, that the LCRL for DBCP was approximately $0.038 \mu\text{g}/\text{m}^3$ for a target volume, and there was a very large percentage of sampled levels below the LCRL. The mechanism for calculating average concentrations, when there was more than one value above the LCRL, was to use a value of one-half the LCRL for all levels reported below the CRL. In rare cases, this scheme skewed the computed average to a value well above what might be expected. Because there were fewer values above the LCRL, this situation occurred with the computation of the DBCP average concentration.

During the IRA-F program, DBCP was detected one to three times at sites FC-1 through FC-5, with a maximum number of detections at FC-1. In addition, the three highest values cannot be used to estimate the distribution of the remainder of the samples. Since the AAC for DBCP was well below the LCRL, and since there were only a few detections of this compound, it is not possible to provide a more detailed analysis of the comparison of observed values to AACs.

The sampling and analytical methods necessary to detect DBCP at its carcinogenic threshold ($0.0004 \mu\text{g}/\text{m}^3$) have not been developed as of the sampling period of the IRA-F. Until such

Table 6.4-2 Comparison of AACs for Chronic Exposure to Off-site Residents to Estimated Maximum Concentration (ug/m³) at any IRA-F Site

	Small children		Adult		Sampled	Dispersed
	AAC Noncarc.	AAC Carc.	AAC Noncarc.	AAC Carc.	Value	Value (Basin F Source)
VOCs						
Benzene		0.359		1.34	1.43	0.13
Carbon tetrachloride		0.0806		0.301	0.60	0.054
Chlorobenzene	4.89		18.3		0.03	0.003
Chloroform		0.129		0.483	0.69	0.062
Dibromochloropropane		0.000476		0.00178	0.04	0.0036
1,2-dichloroethane		0.115		0.43	0.07	0.006
Ethylbenzene	280.0		1040.0		0.65	0.059
Methylene chloride	841.0	6.55	3140.0	24.4	1.17	0.105
Methyl isobutyl ketone	19.6		73.0		0.10	0.009
Tetrachloroethylene		5.76		21.5	0.92	0.083
Toluene	557.0		2080.0		3.92	0.35
1,1,1-trichloroethane	293.0		1100.0		1.52	0.14
Trichloroethylene		1.76		6.57	0.44	0.040
o-Xylene	196.0		730.0		0.86	0.077
m- and p-Xylene	84.1		314.0		1.69	0.15
SVOCs						
Aldrin		0.000616		0.0023	0.0018	0.00016
Chlordane		0.00806		0.0301	0.006	0.00054
Dieldrin		0.000655		0.00244	0.013	0.0012
ppDDT		0.0308		0.115	0.0004	0.00004
METALS						
Arsenic		0.000699		0.00261	0.0007	0.00006
Cadmium		0.00172		0.00641	0.0013	0.00012
Chromium	0.000557	0.000256	.00208	0.000954	0.0030	0.00027
Mercury	0.0841		0.314		0.47	0.042

ppDDT = p,p'Dichlorodiphenyltrichloroethane
 NA = Not Applicable
 ND = Not Detected

methods are developed and certified, it is not possible to reliably compare ambient concentrations to AACs.

The dispersed value of Dieldrin is also above its AAC for small children, by a factor of approximately 1.8. Highest post-remedial Dieldrin readings have occurred during the summer of 1990, indicating an increasing concentration, with an evident source around the former Basin F.

Chromium concentrations were also slightly above the chronic AAC, but as noted in Section 4.3, the actual exceedances of the chromium concentrations occurred on only one day, and the source for chromium on that day has been attributed to regional or area sources. On all other days chromium was not detected. It was not possible to provide a sound comparison of the chronic chromium AAC to the adjusted or "dispersed" concentrations because the source of chromium cannot be determined.

6.4.3 Summary

The acute exposures of off-site residents to the target compounds were well below the applicable AACs. For chronic exposures, the on-site workers were not exposed to concentrations above their respective AACs. The chronic (carcinogenic) AACs for adults and small children living at the RMA boundary were exceeded by an adjusted concentration calculated from dispersion patterns and on-site observations. The respective AACs for Dieldrin, dibromochloropropane, and chromium were exceeded under this evaluation, but because there were a series of conservative assumptions used in making the comparison, it is likely that the tendency to exceed AACs has been overestimated. The conservative nature of the comparison must be borne in mind when evaluating the results.

As time passes, the source strength for compounds that exceed the AAC and that have an on-site source may be reduced. This reduction could be brought about by source deterioration (the greatest source strength is in the first few years for many remedial activities), controls (such as

carbon canisters on vents), or by subsequent remedial activities that further control emissions. The long-term change in source strength has not been addressed here, but future remedial activities should act to reduce those emissions, with possible reductions below the AAC.

7.0 CONCLUSIONS

This report focuses on results of the IRA-F air sampling program which has been conducted in the vicinity of Basin F since May 1989. Much of the data from the Basin F Remediation program and the Odor Program and concurrent CMP program have been summarized and discussed in this report.

Analyses of these data were used to characterize potential sources for the air contaminants which were observed, including both RMA and metropolitan Denver influences. The on-site meteorological data collected by the CMP were also used to describe those conditions associated with average and extreme events.

7.1 TOTAL SUSPENDED PARTICULATES

The TSP measured at RMA were derived from two major sources. The first was a continual influx of particulates from the metropolitan Denver area whose impact at RMA depended largely on wind direction and atmospheric stability. The second source of particulates was remedial activity sources which helped contribute windborne dust, particularly during very dry periods. Intense remedial activity was initiated during 1988, and continued until May 1989. These activities were conducted in several stages, including completion of the intrusive activities in December 1988, emplacement of the clay caps on the Basin F floor and waste pile in February 1989, and the completion of all topsoil reseeded work in May 1989. The TSP data clearly reflect the impacts of these activities, with a dramatic reduction in TSP concentrations around Basin F, and to a lesser extent throughout the Arsenal after completion of earthmoving activities. In addition to the obvious impacts from the Basin F remediation efforts, there were other episodes when the impacts from the Denver area overwhelmed impacts from on-site sources. When these episodes occurred, the TSP levels at the eastern and northern boundaries of RMA were well below those reported in the Denver area, and the CMP results from the southern and western boundary locations showed the highest TSP levels.

7.2 RESPIRABLE PARTICULATES (PM-10)

Respirable particulates were generated by dry, windy conditions, but to a much lesser extent than TSP. During the IRA-F sampling period, the PM-10 results indicated minimal impact from Basin F. There was evident impact from the Denver metropolitan area on several occasions, however, with the highest 24-hour maximum concentrations experienced during Phase 4. These extreme conditions were clearly attributable to metropolitan Denver influence.

7.3 VOLATILE ORGANIC COMPOUNDS

During the Basin F remediation activities, Basin F was the apparent source of several VOCs, including bicycloheptadiene, dimethyl disulfide, benzene, toluene and ethylbenzene. Some of these measured emissions may have been generated by heavy equipment utilized during the remediation activity. Chloroform was detected near Basin F, but also was identified near the South Plants by CMP sampling. Levels of VOCs which were attributable to Basin F remediation decreased rapidly with increased distance from the source, and levels at RMA boundaries, as sampled by the CMP, were similar to or less than those within the urban Denver environment. By the FY90 sample year, sampled concentrations of VOCs were generally reduced, with an apparent shift in the higher concentrations from the Basin F vicinity to the western and southern RMA boundaries. This shift indicates the predominance of other urban sources on RMA ambient VOC concentrations.

7.4 SEMIVOLATILE ORGANIC COMPOUNDS

During remediation, Basin F appeared to be the source of several semivolatile organic compounds including Aldrin, Endrin, and Dieldrin. The highest levels of these compounds were detected in the immediate vicinity of Basin F during the height of remediation activity. After completion of containment and remediation, levels of SVOCs in the Basin F area were significantly reduced, but the Basin F area continued to act as a source with highest concentrations in the prevailing downwind direction at the Basin F perimeter. The sample sites remote from the basin recorded essentially background levels.

7.5 MERCURY

Basin F appears to have been a source of mercury during remediation activities, but by the beginning of Phase 4, there were virtually no detections of mercury in any Basin F sampling. During the summer of FY90, however, mercury detections abruptly started to occur, but these levels were reported during a period when comparable field blank detections were being reported. All Phase 4 mercury results above the LCRL must be used with great caution.

7.6 METALS

The highest metals concentrations were recorded during days when TSP and PM-10 concentrations were also high. These high particulates impacts were frequently attributable to off-site sources. During remediation activities, Basin F appeared to be a source of chromium, copper and zinc, which were detected in elevated concentrations in the vicinity of Basin F. Concentrations of these compounds decreased rapidly with distance from Basin F. Following completion of the remediation, metals levels dropped to typical urban concentrations.

7.7 ARSENIC

Ambient monitoring data for arsenic did not indicate impacts from Basin F during or after remediation. While arsenic levels were generally higher during remediation than during Phases 3 and 4 of the post-activity period, the impacts could not be clearly related to a Basin F source. The nature of the source could not be ascertained from the available data.

7.8 COMPARISON TO AACs

A set of AACs was developed for the target compounds for an assumed seven-year exposure period, for both the on-site workers and the off-site residents. Off-site residents were divided into small children (ages 0 to 7 years of age) and adults only. These values were compared, respectively, to the ambient concentrations sampled on site and to the projected or dispersed concentrations at the RMA boundary. All 24-hour concentrations were below their AACs for acute exposure for on-site workers. Estimated concentrations of dibromochloropropane, Dieldrin and chromium were above their long-term or chronic AACs for adults and small children off site.

Further remedial activities and their related reductions in emissions could bring ambient levels below those AACs. In all cases a series of conservative assumptions was used to determine AACs, making it likely that actual AACs are much higher than the reported values.

7.9 GENERAL INTERPRETATIONS

All data presented in this report must be interpreted and used with regard to the limitations of the sampling program. These limitations include the short length of the IRA-F sampling period, analytical limitations, and the fact that samples were collected for a specific number of days. The interpretations must also take into account the extensive impacts of the greater Denver area upon RMA ambient air quality. The apparent seasonal cycle in ambient concentrations must be considered, and the fact that the IRA-F program included two summer seasons and only one winter must also be taken into account. The possibility of anomalous meteorological conditions during the relatively short sampling program must also be considered when the data are used. As additional data are collected under subsequent programs, further conclusions may be developed and refined from these and supplemental data.

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